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The objective was to determine the availability and costs of limestone and similar materials throughout the contiguous United States, thus providing a basis for determining the feasibility and economics of limestone-based SO_2 removal processes for any particular power plant site. Materials covered include limestone, dolomite, chalk, marble, marl, and shell. Information is presented on location of deposits, production rates, F.O.B. quarry costs, transportation methods and costs, expected cost increases, uses, chemical composition, and physical properties. Much of the data is reported nationally, regionally, and on a state-wide basis. The regions were chosen to coincide with those defined by the National Coal Association. The investigation was limited to the contiguous United States. Enormous deposits of carbonate rocks occur in the United States, and reserves are more than adequate for the foreseeable future. The major deposits of carbonate rocks occur in the eastern half of the United States, where the vast majority of fossil fuel-fired power plants are located. Relative to the potential demand for carbonate rocks by power plants, production of these materials is quite large in most states. However, current production is inadequate to supply the potential needs of power plants in several Atlantic coastal regions, notably New England. Limestone is the only type of carbonate rock which is produced in large enough quantities to merit consideration for widespread application. Most of the power plants in the eastern half of the U. S. could be supplied with high calcium limestone at less than \$4.00/ton. Costs for power plants located in western states generally would be higher, owing to the lack of suitable, nearby deposits and other factors. Based on projections of material cost and transportation charges to 1975, the delivered price of limestone to most power plants should not increase by more than \$1.00-2.00/ton.

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AVAILABILITY OF LIMESTONES AND DOLOMITES

TASK #1 FINAL REPORT

Submitted to
ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS
CONTROL SYSTEMS DIVISION
Contract No. CPA 70-68

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THE M. W. KELLOGG COMPANY
A Division of Pullman Incorporated

Research & Engineering Development

Report No. RED-72-1265

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EPA-OAP-CSD CONTRACT NO. CPA 70-68

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OFFICE OF AIR PROGRAMS
CONTROL SYSTEMS DIVISION

by

THE M. W. KELLOGG COMPANY
RESEARCH & ENGINEERING DEVELOPMENT
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I. INTRODUCTION

This report covers work which was performed under Contract No. CPA 70-68, Environmental Protection Agency, Office of Air Programs. Under this contract, work is divided into various tasks, of which Task No. 1 is described in this report.

Most of the power generated, in the United States comes from plants which burn coal or oil as a primary fuel. With the increasingly stringent regulations and restrictions on emission of sulfur oxides into the atmosphere, combined with the difficulty of obtaining low sulfur fuels, much emphasis is being placed on the development of processes which remove sulfur oxides from power plant stack gases. Several of these processes are based on the use of limestone or dolomite as the absorbent. The proximity of adequate limestone deposits to potential users, i.e., fossil fuel-fired power plants, and the relationship of limestone production to possible demand are important considerations in establishing the relative merits of any limestone-based process. The objective ~~of this study~~ was~~, then~~, to determine the availability and costs of limestone and similar materials throughout the contiguous United States, thus providing a basis for determining the feasibility and economics of limestone-based SO_2 removal processes for any particular power plant site.

The reason for undertaking this study was to supplement the experimental work (most of which is sponsored by CSD, OAP) now under way which is directed toward developing dry limestone injection and limestone wet scrubbing processes for SO_2-removal from stack gases. A study to determine availability and cost of limestone is needed since successful development of the process could result in its widespread application, thus requiring substantial quantities of limestone having the required properties. The results of this study should furnish this information.

B1

Materials covered ~~in this study~~ include limestone, dolomite, chalk, marble, marl, and shell. Information is presented on location of deposits, production rates, F.O.B. quarry costs, transportation methods and costs, expected cost increases, uses, chemical composition, and physical properties.

Much of the data is reported nationally, regionally, and on a state-wide basis. Since the study is primarily concerned with limestone availability as it relates to potential consumption by power plants, the regions ~~have been~~ were chosen to coincide with those defined by the National Coal Association and used by them in their annual listing of power plants in the United States.(1) These regions are defined as follows:

B3

REGION	STATES INCLUDED
New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Middle Atlantic	New Jersey, New York, Pennsylvania
East North Central	Illinois, Indiana, Michigan, Ohio, Wisconsin

---

(1) Steam-Electric Plant Factors/1970 Edition, National Coal Association, Washington, D.C., November, 1970

West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
South Atlantic	Delaware, Florida, Georgia, Maryland (incl. Washington, D.C.), North Carolina, South Carolina, Virginia, West Virginia
East South Central	Alabama, Kentucky, Mississippi, Tennessee
West South Central	Arkansas, Louisiana, Oklahoma, Texas
Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
Pacific	California, Oregon, Washington

In all cases, an attempt was made to obtain the latest data available. Complete information on production rates, uses, and average values of various carbonate materials are available for 1968. Some of this information is also available for 1969. Transportation costs are derived from data obtained during the latter part of 1970. Statistics on power plants are based on information compiled for 1969. The timeliness of the data is noted throughout the report, as necessary.

Although other alkaline materials may be suitable for use in removal of sulfur oxides from stack gases, only those materials listed above were investigated during this study. The investigation was ~~also~~ limited to the contiguous United States, i.e., Alaska and Hawaii were not included.

Published material was the source of some of the data in the report, and all publications consulted are listed in the bibliography. However, much of the data is unpublished and was derived from communications with federal and state government agencies, trade associations, and various crushed stone or limestone producers.

II. ACKNOWLEGMENTS

The assistance of many persons active within the limestone industry is gratefully acknowledged. Ronald C. Briggs, Physical Scientist, U.S. Bureau of Mines, provided valuable statistical data on production, uses, and value of crushed stone; Robert M. Koch, President, National Limestone Institute Inc., Robert S. Boynton, Executive Director, National Lime Association, and F. A. Renninger, National Crushed Stone Association, were very helpful in obtaining information, particularly on stone transportation, from companies within the industry; Alfred J. Bodenlos, Geologist, U.S. Geological Survey, furnished highly useful material on location of carbonate rock deposits. Appreciation is also due to the many state geological surveys, which supplied information on the limestone industry within their states, and to the numerous officials of crushed stone companies, who made available vital information on transportation methods and costs.

III. SUMMARY

A. Potential Demand - Power Plants

Most of the power capacity from coal- and oil-fired power plants in the United States occurs in the eastern half of the country. In fact, almost 90% of the major (>200 MW) coal- and oil-fired power plants scheduled to be onstream in 1975 are located east of the Mississippi River. Particularly high concentrations are found in the East North Central region of the United States and in many of the larger metropolitan areas.

Based on 1969 fuel consumption statistics, at least 40 million tons of limestone would have been required to remove the 20 million tons of sulfur oxides emitted by power plants in the United States. The East North Central region was potentially the largest consumer with over one-third of the total limestone. With the exception of New England, other eastern and east central regions also had potentially large demands for limestone.

B. Carbonate Rock Reserves

Deposits of carbonate rocks, including limestone, dolomite, shell, marble, and marl, occur in some form in every state. Total reserves have never been determined, but are known to be enormous.

Based on a United States Geological Survey map showing the areal extent of surface carbonate rocks, and some very simplifying assumptions, an approximate estimate of more than 3.6×10^{11} tons was obtained for total surface carbonate deposits in the United States. About two-thirds of this occurs in the eastern half of the country. Even on the assumption that only 10% of this stone could be commercially extracted, the surface reserves are adequate for over 500 years, at the present rate of consumption. Although these figures should be regarded as very rough approximations, they nevertheless demonstrate the enormity of carbonate deposits in the United States.

Limestone and dolomite deposits are far more abundant in the eastern half of the country where they commonly outcrop in large, thick, horizontal beds. Limestone outcrops are particularly plentiful in an area extending from eastern Kansas and Nebraska eastward to the Appalachian Mountains, and reaching southward from the Great Lakes into central Alabama. Many of these deposits contain high calcium stone (>95% calcium carbonate). Limestone also is found in most other eastern and east central states, notably in Florida; it does not occur in most Atlantic coastal regions, however.

Dolomite, a stone containing both calcium and magnesium carbonates, abounds in states surrounding the Great Lakes, and along the Appalachian Mountains from Vermont to central Alabama. High grade deposits (a dolomitic stone containing >95% total carbonates) are common.

Most limestone and dolomite deposits in western and west central states tend to be discontinuous, scattered, and, in mountainous sections, occur frequently as steeply dipping beds. Although not as abundant as in the east, nevertheless, high purity limestones and dolomites occur in many areas.

The most significant deposits of marble are found along virtually the entire length of the Appalachian Mountains in the east, and as scattered occurrences in the Rocky Mountains in the west. Although eastern marbles are predominantly calcitic (high calcium), dolomitic types also occur. Both types are found in the west.

Shell limestone occurs primarily in Gulf Coastal waters, but it also is found in bay waters along both the east and west coasts. It is usually a very pure type of calcium carbonate.

Marl deposits exist in several areas, notably around the Great Lakes, and along the southeastern coastal plain. This soft, relatively impure form of calcium carbonate varies considerably in character, that of the Great Lakes area being a precipitated calcium carbonate, while that of the coastal plain is an impure shell deposit. Limited occurrences in other regions are generally impure chalks or soft limestones.

C. Properties

Physical properties vary with composition, crystal structure and the nature of impurities. Typical ranges for the more important properties are summarized in Table 1.

Some properties which influence grindability are shown in the table. Abrasive loss, as measured by the Deval and Los Angeles methods, is expressed as the percentage of material passing a 12-mesh screen after a sample has been subjected to a standardized test in a rotating drum. The Dorry hardness test consists of subjecting a sample to the abrasive action of finely crushed quartz. The higher the number is, the harder is the material. Toughness is measured by dropping a known weight on a standard specimen. The height of fall at failure is termed the toughness. These terms, and the test procedures, are fully explained in the report.

For purposes of comparison of the properties mentioned in the preceding paragraph, a range of values reported for 20 of

TABLE 1

TYPICAL PHYSICAL PROPERTIES OF CARBONATE ROCKS

	LIMESTONE	CHALK	DOLOMITE	MARBLE	PRINCIPAL NON-CARBONATE ROCKS[1]
Specific Gravity	2.71[2]	-	2.8-2.9	-	-
Bulk Density, lb/ft^3	155-175	100-125	160-180	165-180	-
Porosity, vol. %	0.3-6.0	10-40	0.3-6.0	0.1-1.0	-
Abrasive Loss					
Deval, %	3.5-8.5	-	3.5-8.5	4-10	1.5-22
Los Angeles, %	17-35	-	16-35	23-67	10-70
Crushing Strength, psi x 10^3	10-28	1-4	10-40	10-30	28-67[3]
Dorry Hardness[4]	10-17	-	11-17	9-17	6-20
Toughness[5]	4-13	-	4-14	3-9	3-32

---

[1] Including Amphibolite, Basalt, Breccia, Chert, Conglomerate, Diabase, Diorite, Eclogite, Epidosite, Felsite, Gabbro, Gneiss, Granite, Peridotite, Quartzite, Sandstone, Schist, Serpentine, Slate, Syenite

[2] For Calcite. Aragonite is 2.94

[3] For Basalt, a dense, fine-grained rock

[4] The hardest rocks have the largest values

[5] The toughest rocks have the largest values

the principal non-carbonate rock types is included in Table 1.

Few of the properties shown in Table 1 have been determined for shell and marl.

D. Mining

Carbonate stones are recovered by several methods, including underground mining and dredging, but quarrying is employed most commonly. After removal of overburden and primary blasting of the stone, various crushing, grinding, sizing, and cleaning operations are performed to produce a range of marketable products. A large, modern quarry is an expensive, complex, and highly mechanized unit.

Over 4,700 quarries, producing 861 million tons of crushed stone of all types, were in operation in the United States in 1969. Since production of crushed carbonate rocks totaled 652 million tons, it can be assumed that, roughly, over 3,500 of these quarries produced limestone, dolomite, and related stones. More than one-third of all quarries had annual production rates of less than 25,000 tons. The large operations (over 900,000 tons/year) produced one-third of the total crushed stone, although they represented less than 4% of the total number of quarries.

E. Production

Crushed carbonate rock production in the United States in 1969 was distributed as follows:

	MM TONS
Limestone	559
Dolomite	68
Shell	20
Calcareous Marl	2.5
Marble	2.3
Total	652

No production of any type was reported in three states, viz., Delaware, New Hampshire, and North Dakota. These states, plus Louisiana, were the only states which did not produce any limestone. Dolomite was produced in twenty-four states, chiefly in the northeastern quarter of the country.

Production of limestone and dolomite, by region, was as follows:

	MM TONS
New England	2.4
Middle Atlantic	90.9
East North Central	185.6
West North Central	92.5
South Atlantic	87.5
East South Central	81.3
West South Central	58.3
Mountain	10.7
Pacific	18.8
Total	628

Nationwide, Pennsylvania and Illinois were the leading producers of limestone and dolomite, respectively. Within most regions, production rates of individual states varied from near zero to tens of millions of tons. The New England and Mountain regions, however, had fairly uniform, and low, outputs. The East North

Central region was also an exception, with all states reporting large quantities of limestone and dolomite, ranging from 16 to 55 million tons.

Shell was dredged from bay waters along all three coasts. However, 83% came from Texas and Louisiana, with the latter being the leading producer. Small quantities of marl were produced in Indiana, Michigan, Minnesota, Mississippi, Nevada, South Carolina, Texas, and Virginia. Eighteen states, principally in eastern and western mountainous regions quarried marble, with Alabama recording the highest production at 632,000 tons.

F. End Use

Carbonate rocks are unique among the different types used in this country. Not only do they find use in applications where their physical properties are important, but also in markets which utilize them for their chemical properties and composition. Almost two-thirds of the total production of carbonate rocks were used for various construction purposes in 1969. Most of this stone was used as an aggregate material in road construction. The second largest use was in cement manufacture, which consumed over 105 million tons. About 70 million tons of high grade limestone and dolomite were used in lime manufacture and other applications requiring a high purity material.

G. Unit Values

The average unit value, or net selling price at the quarry, for all crushed carbonate stones produced in the United States in 1969 was $1.49/ton and varied by type of stone as follows:

Limestone	$1.45/ton
Dolomite	$1.55/ton
Shell	$1.42/ton
Marl	$1.01/ton
Marble	$9.69/ton

The high unit value of marble reflects its primary use as a decorative material.

Unit value also varies with end use. Stone used for all construction purposes averaged $1.44/ton while stone used in applications requiring a high purity material had an average value of $1.69/ton. Average prices ranged from $0.69/ton for fill to $6.00/ton for exposed aggregate (decorative stone). Stone for most applications, however, averaged under $2.00/ton. The variation in price depends not only on supply and demand, but also on the chemical and/or physical properties required for the particular application.

Average prices of limestone and dolomite were $1.00 - 2.00/ton in most states, although spot prices ranged from $0.12 - 25.00/ton. However, several states in the New England and Mountain Regions, in addition to New Jersey, reported average values above $2.00/ton. Rhode Island reported the highest average value: $7.57/ton for limestone. The prices reported in California and Washington were unusual in that average values for limestone were below the national average, while average values for dolomite far exceeded $2.00/ton. In all cases where average unit values were high, production of the particular stone was limited.

With the exception of Virginia, which reported $3.92/ton, average prices of shell were $1.00 - 2.00/ton. Unit values for marl were all below $1.15/ton. Marble varied widely in price.

H. Transportation

Trucks dominated in the transportation of carbonate rocks from quarry to consumer, accounting for almost three-fourths of all stone. Rail and waterway hauls, amounting to one-fifth of the stone shipments, were about equally divided.

Trucks generally are used for shorter hauls of under 50-100 miles, while rail is employed for longer distances. Where conditions permit, shipment of stone by barge or boat is preferred, since this is usually the cheapest method of transportation.

Typical capacities of the various vehicles used to transport stone are:

Truck	up to 50 tons
Rail Car.	60-100 tons
Barge	1200-1400 tons
Boat.	up to 29,000 tons

Trucks were a popular mode of transportation in all sections of the nation, while railroads were important in eastern states, particularly in the southeast. Large amounts of stone were moved via inland waters, notably in the Great Lakes area and along the Gulf Intercoastal Waterway. The abundance of highways, railroads, and inland waterways found in the east is not duplicated in western states, thereby limiting the selection of a transportation method in the latter area.

Generally, sufficient trucks, barges, and boats are available to haul stone, although in some areas, and in peak seasons, the supply may be limited. In most sections of the country, however, a shortage of rail cars does occur. For a power plant, where the limestone demand would be known and deliveries, therefore, could be scheduled well in advance, the affect of a shortage of vehicles should not be severe.

So many factors influence transportation rates and costs that it becomes very difficult to establish average rates, even within a single area. Most freight rates for crushed stone in the United States, however, fall within the following ranges, in cents per ton-mile:

Truck	5.0-10.0 (@10 miles)	→	2.0 -5.0 (@100 miles)
Rail	4.5- 6.0 (@10 miles)	→	0.75-1.5 (@250 miles)
Water	0.9- 1.5 (@20 miles)	→	0.25-0.50(@500 miles)

I. Delivered Price

The delivered price of limestone to 37 selected power plants was estimated based on the assumption that a high calcium limestone would be required. Most of the plants are located in the eastern half of the United States where the major coal- and oil-fired power capacity is found. Prices range from $1.95-13.20/ton. Half of the plants could be supplied at under $4.00/ton, while all but 3 could obtain limestone at under $6.00/ton. The latter 3 plants are located in the west in areas where base prices are higher or limestone deposits are remote. For several eastern seaboard plants, particularly in New England, the availability of low-cost high calcium limestone is contingent upon the acceptability of an imported stone. Domestic sources are either inadequate or too distant to provide a low-cost material.

J. Future Costs

Carbonate rocks historically have been stable, low-priced commodities. Based on average unit values for the years 1960-1969, projected average base prices for 1975 are as follows:

	1969	1975
Limestone and Dolomite	$1.46/ton	$1.67-1.82/ton
Marl	$1.01/ton	$1.28-1.48/ton

The average value of shell has dropped considerably since 1960. It is unlikely that it will continue to decrease through 1975. More probably, it should parallel limestone and dolomite but not exceed them in value. Average unit values for crushed marble are highly variable, reflecting the sensitivity of price to market conditions.

Transportation rates during the next 5 years should rise about 6%/year, on the average. Estimates by type of transportation are as follows:

Truck	4- 6%/year
Rail	6- 8%/year
Water	5-10%/year

These estimates, based on predictions by various stone producers, assume a continuance of the present rate of inflation.

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study described in this report, the following conclusions and recommendations are made regarding the availability and cost of limestone and dolomite for air pollution control:

from p 3

- Enormous deposits of carbonate rocks occur in the United States, and reserves are more than adequate for the foreseeable future. A very rough approximation of surface carbonate deposits indicates a minimum of 3.6×10^{12} tons, sufficient to satisfy national requirements for more than 500 years at the present rate of consumption (and assuming a 10% availability of these reserves). Availability of high purity stone may become a problem several decades hence, but, with the probability that the required quality will depend on other process and economic factors, no shortage of suitable stone is foreseen.

- The major deposits of carbonate rocks occur in the eastern half of the United States, where the vast majority of fossil fuel-fired power plants are located. Large reserves in these eastern areas provide a nearby source of stone for most power plants. Roughly two-thirds of all surface deposits of carbonate rock are found in the eastern half of the country.

- Relative to the potential demand for carbonate rocks by power plants, production of these materials is quite large in most states. However, current production is inadequate to supply the potential needs of power plants in several Atlantic coastal regions, notably New England.

t. p. 17

from p. 16

- Limestone is the only type of carbonate rock which is produced in large enough quantities to merit consideration for widespread application in the removal of SO_x from stack gases. In many areas, however, ample amounts of other carbonate rocks are produced, particularly dolomite.

- Most of the power plants in the eastern half of the United States could be supplied with high calcium limestone at less than $6.00/ton. Many could obtain stone at less than $4.00/ton. Costs for power plants located in western states generally would be higher, owing to the lack of suitable, nearby deposits and other factors.

The preceding costs are based on an unsized, nominally 2-6" x 0(1) stone, which is typical of the product from the primary crusher at most quarries. If a sized or fine material is desired, the cost may increase. However, most quarries have little or no capacity for fine grinding, particularly in the amounts required by the larger power plants.

- Based on projections of material cost and transportation charges to 1975, the delivered price of limestone to most power plants should not increase by more than $1.00-2.00/ton.

- The data and material contained in this report should be used to obtain a first approximation of the occurrence, characteristics, and cost of carbonate rocks in a particular case, thereby enabling a power company to assess the desirability of installing a limestone-based process for SO_x removal. If further investigation is warranted, the state geological surveys, a list of which is included in the report, individual stone producers, and local carriers should be consulted for more detailed and specific information.

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(1) This indicates stone with a maximum size of 2-6" and no minimum size.

V. DEFINITIONS

To avoid some of the confusion which frequently results from the inexact and qualitative definitions applied to limestone and related materials in the United States, and from the multitude of overlapping names used, some of the terms as used in this report are defined below.

Limestone is a general term applied to sedimentary rocks composed chiefly of calcium carbonate, $CaCO_3$, calcium-magnesium carbonate, $CaMg(CO_3)_2$, or mixtures of the two. The term is also used, in a more restricted way, to denote rocks composed mainly of calcium carbonate, in order to differentiate them from dolomites. Dolomite is a name used to describe a limestone primarily composed of the mineral dolomite, calcium-magnesium carbonate ($CaMg(CO_3)_2$). It is generally applied to carbonate rocks which contain approximately 20% or more magnesium carbonate, $MgCO_3$. Pure dolomite would contain 54.3% $CaCO_3$ and 45.7% $MgCO_3$. A point of contention, which is sometimes noted in the literature, is whether the calcium and magnesium carbonates are chemically combined, or whether they occur merely as a physical mixture. Limestone and dolomite occur with varying quantities of impurities, the most common of which are silica, alumina, iron oxides, and carbonaceous matter.

Lime can be defined as the product which results from calcination of a limestone or dolomite. Calcination is a process of heating the stone to a temperature at which carbon dioxide, CO_2, is released, thereby converting the carbonates to oxides. A calcium carbonate stone will produce a lime containing calcium oxide, CaO. Dolomite will produce a lime containing both calcium oxide and magnesium oxide, MgO, commonly called magnesia. In practice, commercial limes are usually derived from high purity stones containing a minimum of about 95% total carbonates.

The following list defines the more important terms used in this report:

Aragonite is a mineral composed of calcium carbonate, and having an orthorhombic crystalline structure.

Argillaceous limestone contains clay as a major impurity.

Bituminous (carbonaceous) limestone contains organic compounds as a major impurity.

Calcareous is a term used to describe any material containing calcium carbonate.

Calcite is a mineral composed of calcium carbonate, and having a rhombohedral crystalline structure. It is the predominant mineral in most limestones.

Chalk is a soft, friable, fine-grained limestone consisting primarily of the remains of minute marine organisms.

Coral limestone is a fossiliferous limestone consisting primarily of coral.

Dolomitic limestone refers to a limestone which contains more than approximately 20% magnesium carbonate. The term is usually interchangeable with "dolomite".

Ferruginous limestone contains iron oxides as a major impurity.

Flux stone is a high-purity limestone or dolomite used as a flux in metallurgical processes. It contains 95% or more minimum total carbonate.

Fossiliferous limestone is a stone in which the shells or shell fragments (fossils) are readily discernible.

High calcium limestone refers to a limestone which contains a minimum of approximately 95% calcium carbonate.

Magnesian limestone refers to a limestone which contains magnesium carbonate within the approximate range of 5-20%.

Marble is a metamorphic rock consisting of crystallized grains of calcite and/or dolomite. Commercially, the definition includes any calcareous rock that can be polished.

Marl is an indefinite term used to describe a loose, soft, impure material which contains fine-grained fragments of shell and marine organisms intermixed with sand and clay.

Oolitic limestone contains small, rounded pellets (oolites), having a center of calcium carbonate or sand grains around which are deposited concentric layers of calcite.

Shell limestone is a term used to describe limestone derived from clam and oyster shells.

Siliceous (cherty) limestone contains silica as a major impurity.

Travertine consists of calcium carbonate that is chemically precipitated from hot springs.

VI. POTENTIAL DEMAND FOR LIMESTONE

A. Use of Limestone for Pollution Control

Power plants which use coal or oil as the primary fuel account for most of the power generation in the United States, with coal by far the most common fuel. In general, the more abundant reserves of these fuels are relatively high in sulfur content and their use results in large quantities of sulfur oxides being emitted to the atmosphere. Federal, state, and city regulations are becoming increasingly more stringent, causing some power plants, for example, in the large metropolitan areas, to convert to low sulfur fuels. These are available in only limited quantities and are costlier than the far more abundant supplies of high sulfur fuels. This fact, coupled with growing public concern over air pollution, and proposed legislation have spurred interest in an alternate approach to the problem, the development of processes which remove sulfur oxides from power plant stack gases.

Limestone and related materials have been found to be promising candidates for such processes. The primary components of limestone, calcium carbonate and magnesium carbonate, remove sulfur oxides from stack gases through a series of reactions some of which are as follows:

$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2 \tag{1}$$
$$CaCO_3 + SO_2 + 1/2\ O_2 \rightarrow CaSO_4 + CO_2 \tag{2}$$
$$CaCO_3 + SO_3 \rightarrow CaSO_4 + CO_2 \tag{3}$$
$$MgCO_3 + SO_2 \rightarrow MgSO_3 + CO_2 \tag{4}$$
$$MgCO_3 + SO_2 + 1/2\ O_2 \rightarrow MgSO_4 + CO_2 \tag{5}$$
$$MgCO_3 + SO_3 \rightarrow MgSO_4 + CO_2 \tag{6}$$

Limestone-based sulfur removal processes are now well into the development stage, and comprehensive large-scale test work is being done. The most prominent limestone processes are the dry-injection process and the wet-scrubbing process. In the dry-injection process, hot combustion gases are contacted with powdered limestone which is injected into the furnace above the burners. The solid reaction products and unreacted material is collected in dry form along with the fly ash in standard dust collection equipment. The wet-scrubbing process uses a recirculating limestone slurry to contact the stack gases in a scrubber located downstream of the power plant air preheater. In this case, the additive material and fly ash are collected in the form of wet solids. A promising variation is a combination of the two processes wherein the limestone is injected in dry form and the gas-solids stream is further treated in a wet-scrubbing circuit. A detailed discussion of these processes and their relative merits is given elsewhere.(1) (2)

Successful development of these processes is one potential solution to part of the air pollution problem. It would permit power plants burning high sulfur fuels to continue to do so and yet, at the same time, to reduce their sulfur emissions to acceptable levels. It also would give power plants which now are required to burn low sulfur fuels the option to convert to high sulfur fuels without increasing their sulfur emissions. Additionally, it would allow gas-fired power plants to switch to coal or oil without causing severe pollution problems. The importance of this is emphasized by the dwindling natural gas reserves in this country.

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(1) "Conceptual Design and Cost Study, Sorption by Limestone or Lime Dry Process", TVA, 1968.

(2) "Conceptual Design and Cost Study, Use of Limestone in Wet-Scrubbing Process", TVA, 1969.

Specifications for limestone to be used in these sulfur removal processes have not yet been completely defined. Limestone, dolomite, marl, lime, and coral are among the materials that have been and are being tested. It is likely that a high purity carbonate rock would be desirable, in order to minimize the amount of inerts that must be handled, but no limits on carbonate content have yet been set. Most test work has been done on finely ground rock, but final particle size specifications have not been determined. It is possible that process specifications as to type of material, required purity, size, etc., will result from an economic balance between process performance and cost of different stones at a particular power plant site.

B. Major Power Plants Designed for Coal and/or Oil

Figure 1 shows the approximate location of most of the major power plants in the United States which were, or will be, designed to burn coal and/or oil. These are plants having installed generating capacities of 200 megawatts (MW) or greater that are either in existence now or are scheduled to come on stream by 1975. Some of these are designed also to burn natural gas, in addition to coal and/or oil. Most, but not all, plants which fit the above definition are shown. There are a few which are scheduled to come on stream between now and 1975 for which no information is available on plant site, type of fuel, or both. These have been excluded from the map.(1) (2)

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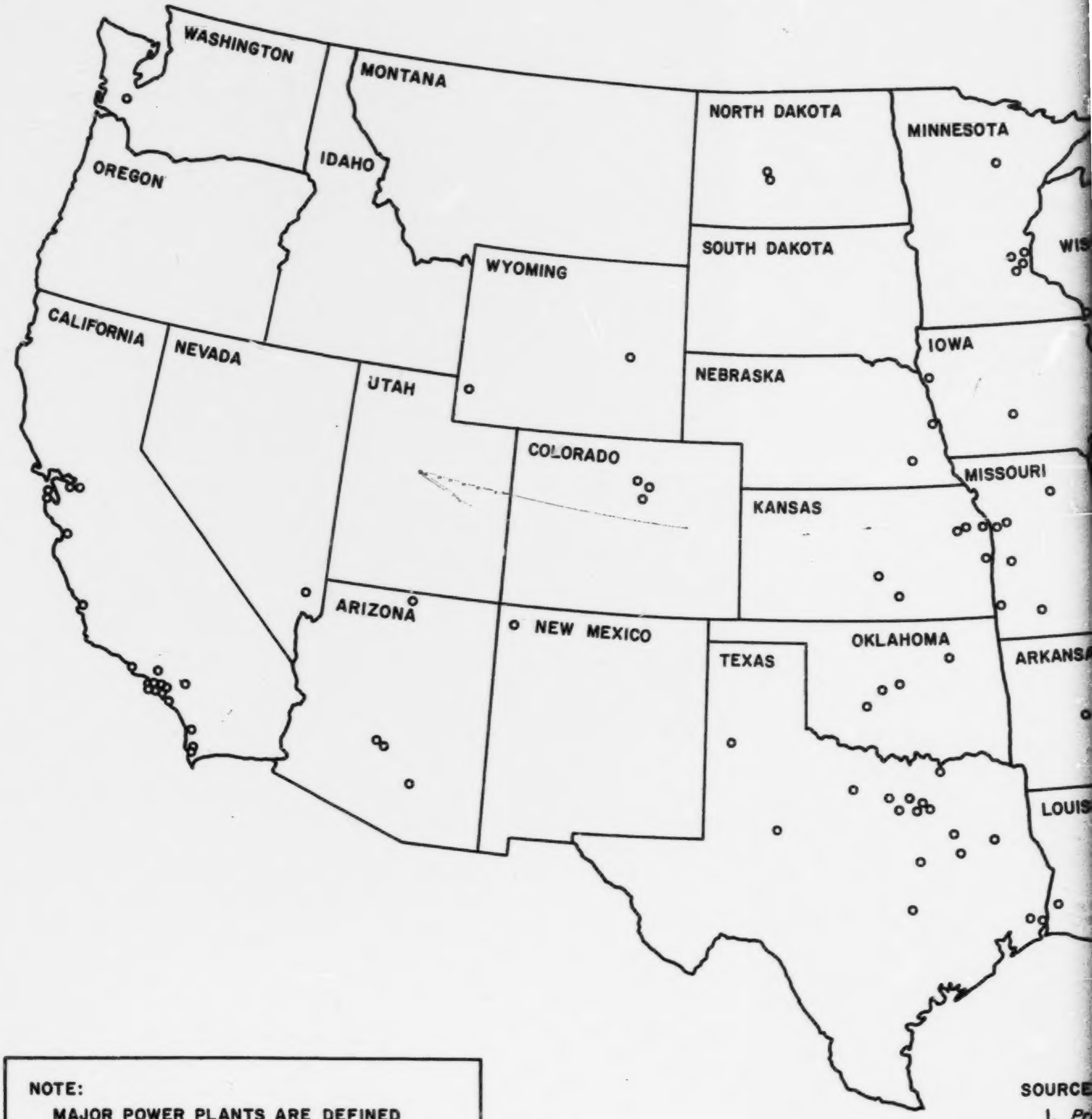
(1) Steam-Electric Plant Factors/1970 Edition, National Coal Association, Washington, D.C., November, 1970.

(2) Principal Electric Facilities, Federal Power Commission, 1970. (Series of Seven maps)

FIGURE 1

MAJOR THERMAL POWER PLANTS IN THE DESIGNED TO BURN COAL AND/O

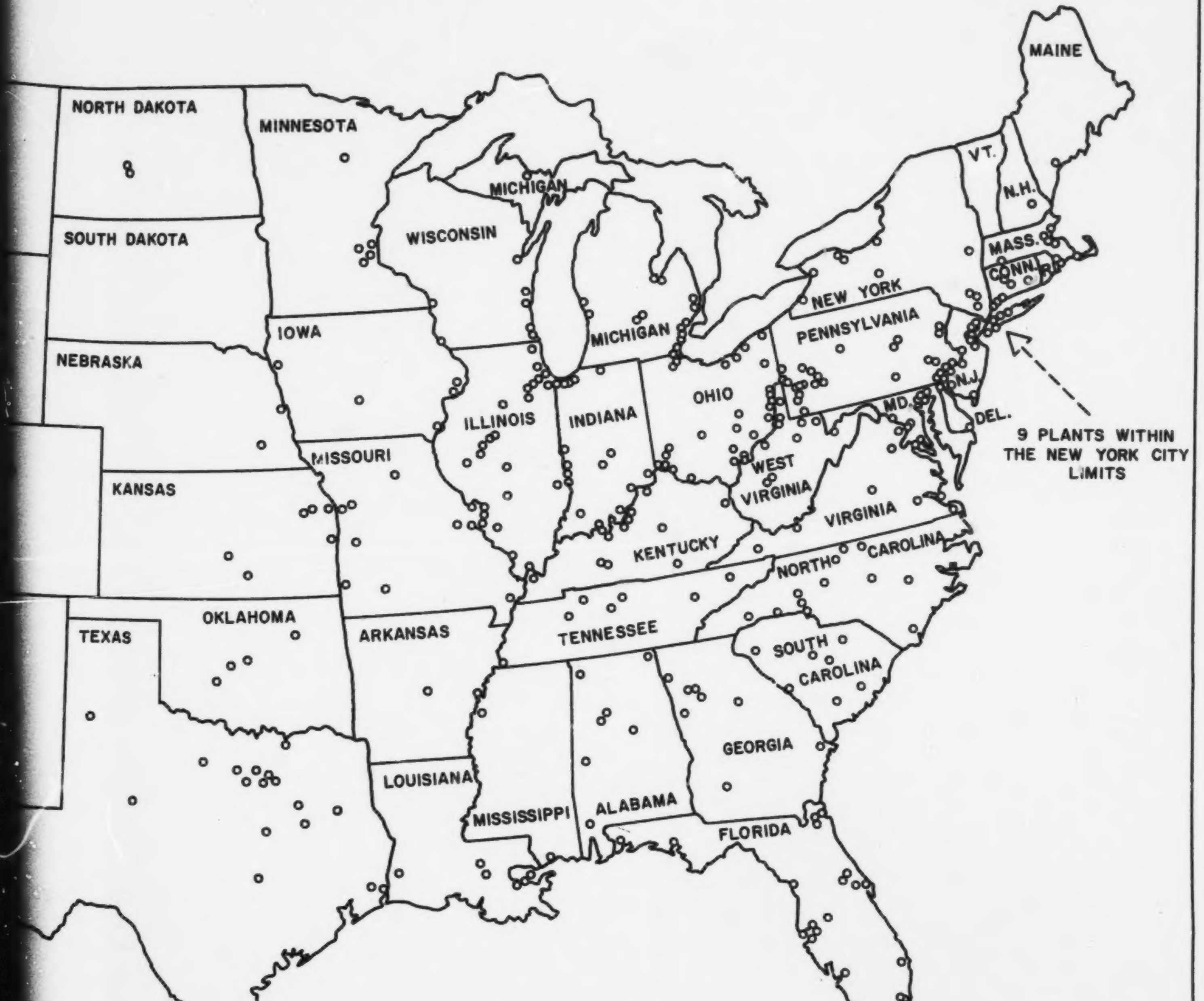

WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WIS
WYOMING
CALIFORNIA
NEVADA
IOWA
UTAH
NEBRASKA
COLORADO
MISSOURI
KANSAS
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSA
TEXAS
LOUIS

NOTE:
MAJOR POWER PLANTS ARE DEFINED
AS THOSE HAVING INSTALLED GENERATING
CAPACITIES OF 200 MEGAWATTS OR MORE.

SOURCE
1. *Pr*
2. *St*

FIGURE 1

HERMAL POWER PLANTS IN THE UNITED STATES DESIGNED TO BURN COAL AND/OR OIL


NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
MICHIGAN
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW YORK
IOWA
NEBRASKA
MICHIGAN
PENNSYLVANIA
N.J.
OHIO
ILLINOIS
INDIANA
MD.
DEL.
MISSOURI
KANSAS
WEST VIRGINIA
VIRGINIA
KENTUCKY
NORTH CAROLINA
TEXAS
OKLAHOMA
ARKANSAS
TENNESSEE
SOUTH CAROLINA
GEORGIA
LOUISIANA
MISSISSIPPI
ALABAMA
FLORIDA

9 PLANTS WITHIN THE NEW YORK CITY LIMITS

SOURCES:

1. *Principal Electric Facilities,* Federal Power Commission, (1970). (Series of seven maps)
2. *Steam-Electric Plant Factors/1970 Edition,* National Coal Association, Washington, D.C., (November 1970).

The selection of 200 MW as a minimum size for representation of power plants in Figure 1 was arbitrary. However, since these larger plants account for more than three-fourths of the power capacity of all conventional power plants in the United States, it is felt that they adequately describe the coal- and oil-fired power capacity in this country.

There are 361 plants shown on Figure 1. Inspection of the map reveals that most of these are located in the eastern half of the United States with a high concentration in the East North Central, South Atlantic, and Middle Atlantic regions. Particularly noteworthy is the very high densities indicated in the major metropolitan areas such as New York City, Pittsburgh, Detroit, Chicago, etc.

About 75% of these plants are within states that lie wholly east of the Mississippi River. Pennsylvania has more (28) than any other state. Table 2 is a tabulation by region and shows that the East North Central region contains almost one-quarter of these power plants. The Mountain region has the fewest with just 3.1% of the total.

C. Major Power Plants Using Coal or Oil

Figure 2 shows the approximate location of most of the major power plants in the United States which burn either coal or oil as the primary fuel. Included on the map are a few plants which, although not yet constructed, are being designed exclusively for either coal or oil. A few others, where sufficient information to establish location or primary fuel is lacking, have been omitted. The power plants shown on Figure 2 have been defined in a similar manner to those

TABLE 2

MAJOR POWER PLANTS IN THE UNITED STATES DESIGNED FOR COAL/OIL(1)

Region	No. of Plants	% of Total
New England	16	4.4
Middle Atlantic	62	17.2
East North Central	86	23.8
West North Central	30	8.3
South Atlantic	78	21.6
East South Central	28	7.8
West South Central	29	8.0
Mountain	11	3.1
Pacific	21	5.8
Total	361	100.0

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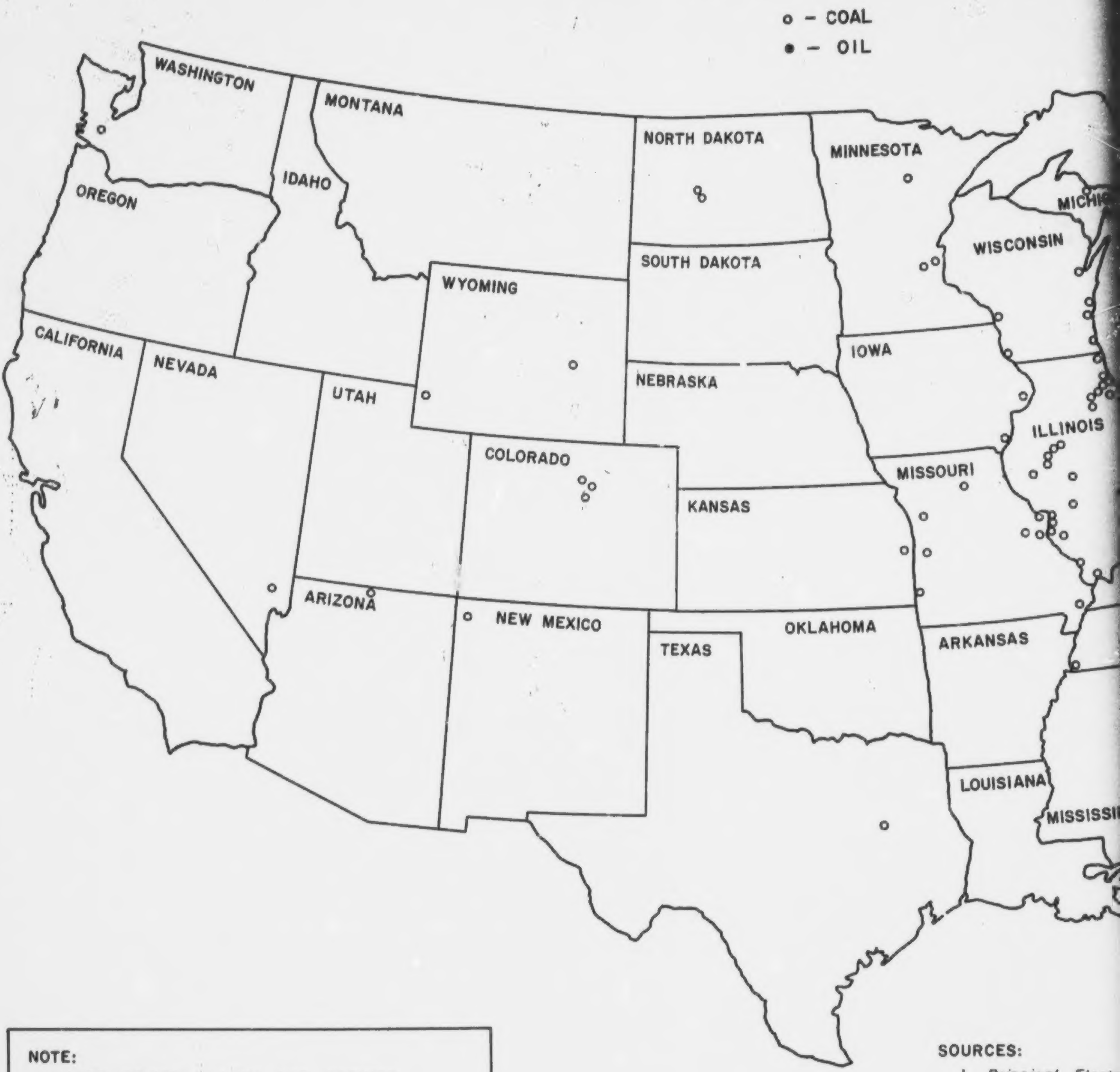
(1) See Section VIB of text for definition

FIGURE 2

MAJOR THERMAL POWER PLANTS IN THE UNITED S

BURNING COAL OR OIL AS THE PRIMARY FUE



○ - COAL
● - OIL
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
IDAHO
OREGON
MICHIG
WISCONSIN
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
UTAH
IOWA
NEBRASKA
ILLINOIS
COLORADO
MISSOURI
KANSAS
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
ARKANSAS
LOUISIANA
MISSISSI

NOTE:

MAJOR POWER PLANTS ARE DEFINED AS THOSE HAVING INSTALLED GENERATING CAPACITIES OF 200 MEGAWATTS OR MORE.

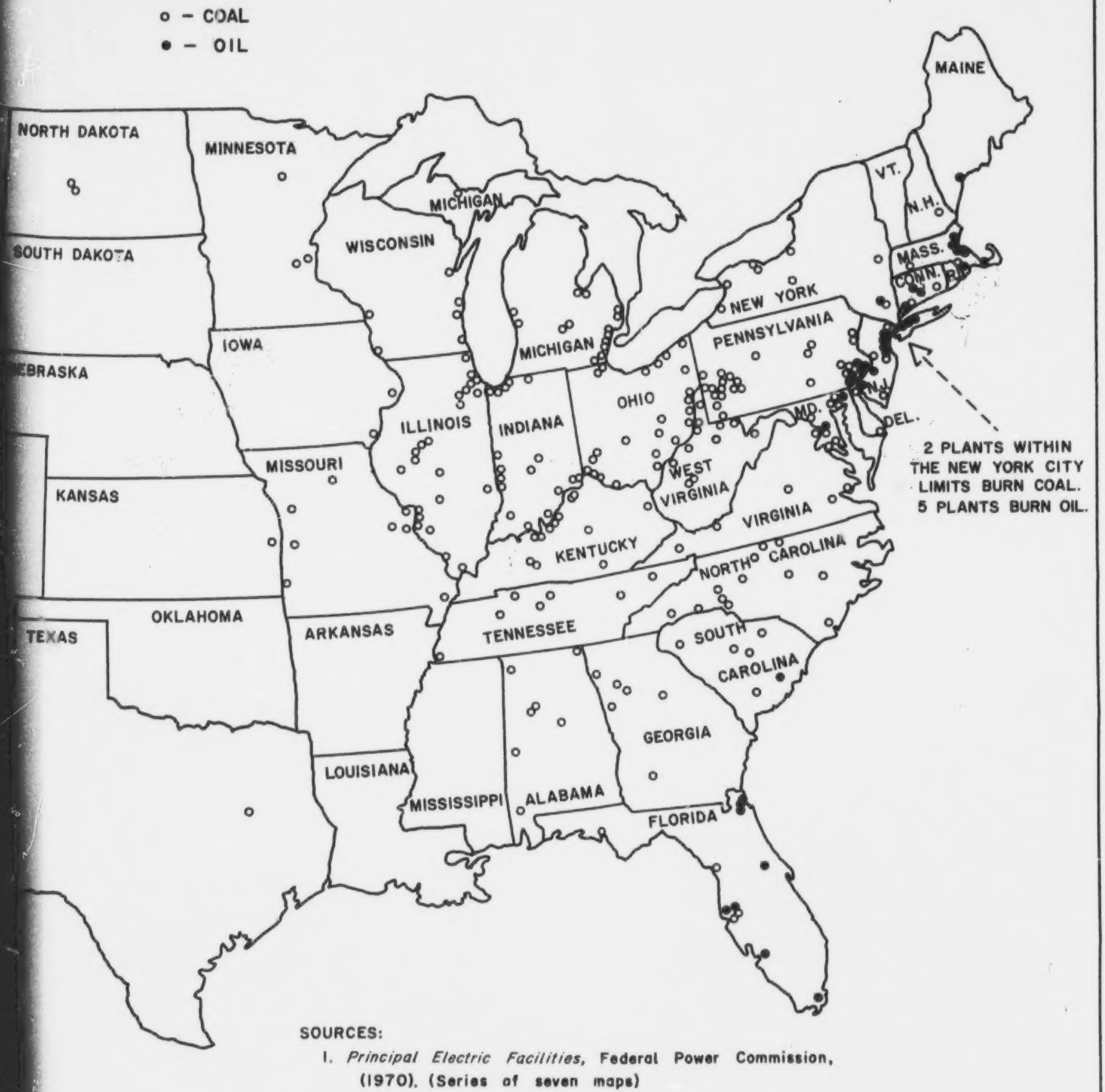
SOURCES:

1. *Principal Electr*
(1970). (Serie

2. *Steam-Electric*
Coal Associ

FIGURE 2

MAL POWER PLANTS IN THE UNITED STATES
G COAL OR OIL AS THE PRIMARY FUEL


○ – COAL
● – OIL
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
MICHIGAN
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW YORK
PENNSYLVANIA
IOWA
EBRASKA
MICHIGAN
OHIO
ILLINOIS
INDIANA
N.J.
MD.
DEL.
MISSOURI
KANSAS
WEST VIRGINIA
VIRGINIA
KENTUCKY
NORTH CAROLINA
TEXAS
OKLAHOMA
ARKANSAS
TENNESSEE
SOUTH CAROLINA
GEORGIA
LOUISIANA
MISSISSIPPI
ALABAMA
FLORIDA

2 PLANTS WITHIN THE NEW YORK CITY LIMITS BURN COAL. 5 PLANTS BURN OIL.

SOURCES:

1. *Principal Electric Facilities*, Federal Power Commission, (1970). (Series of seven maps)
2. *Steam-Electric Plant Factors/1970 Edition*, National Coal Association, Washington, D.C., (November 1970).

shown on Figure 1; i.e., they are plants having installed generating capacities of 200 MW or greater that are either in existence now or are scheduled to come on stream by 1975. (These plants account for more than 60% of the power capacity of all conventional power plants in the United States.)

Inspection of the map shows that, by far, most of these plants use coal as the primary fuel. In fact, 84% of the 275 plants shown can be considered coal-fired power plants. The oil-fired plants are all located along the eastern coast of the United States and almost 50% of these are in the Middle Atlantic region.

Comparison of Figure 2 to Figure 1 shows a striking dissimilarity in the states in the western half of the country. This is owing to the fact that although many plants in this area were designed to run on a variety of fuels, they, in fact, use gas as the primary fuel. 205 of the total of 231 coal-fired plants shown, or almost 90%, are located within states that lie wholly east of the Mississippi River.

The pattern illustrated in the eastern half of the United States is very similar to that shown on Figure 1 in that the East North Central, South Atlantic, and Middle Atlantic regions, and the major metropolitan areas show the highest concentrations of coal-fired power plants. Ohio and Pennsylvania have more major coal-fired power plants (23 each) than any of the other states, while New York (with 9) leads the list of states with major oil-fired plants.

Table 3 summarizes the data by region and shows that the East North Central region contains over 30% of these power plants. The West South Central and Mountain regions have the lowest percentage, 0.4%, each region having only one plant.

TABLE 3

MAJOR POWER PLANTS IN THE UNITED STATES BURNING COAL OR OIL AS THE PRIMARY FUEL[1]

Region	Coal-Fired Plants	Oil-Fired Plants	Regional Total	% of Total
New England	6	10	16	5.8
Middle Atlantic	37	21	58	21.1
East North Central	83	-	83	30.2
West North Central	16	-	16	5.8
South Atlantic	53	13	66	24.0
East South Central	26	-	26	9.4
West South Central	1	-	1	0.4
Mountain	8	-	8	2.9
Pacific	1	-	1	0.4
Total	231	44	275	100.0

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(1) See Section VIC of text for definition

D. Potential Limestone Demand

The preceding two sections geographically locate the major sources, or potential sources, of air pollution resulting from emissions of large quantities of sulfur oxides (SO_x) from power plants. This section deals with the potential demand for limestone by power plants in the United States. As a basis, the actual 1969 consumption of coal (tons) and oil (barrels) in the United States, as reported by the National Coal Association in "Steam-Electric Plant Factors/ 1970 Edition", was used. These data cover virtually all of the coal- and oil-fired power plants. In order to translate coal and oil consumption into potential limestone demand, the following assumptions were made:

1) All power plants for which coal and oil consumption data are available use a limestone-based process for sulfur removal.

2) Coal has a sulfur content of 3.0%.

3) Oil has a sulfur content of 2.0% and a density of 7.4 lb/gal.

4) All sulfur in the fuel is burned to SO_x and exits in stack gas.

5) The limestone used has a composition of 95% $CaCO_3$ and 5% inerts.

6) A 25% excess (based on stoichiometry) of limestone is required to remove 90% of the SO_x.

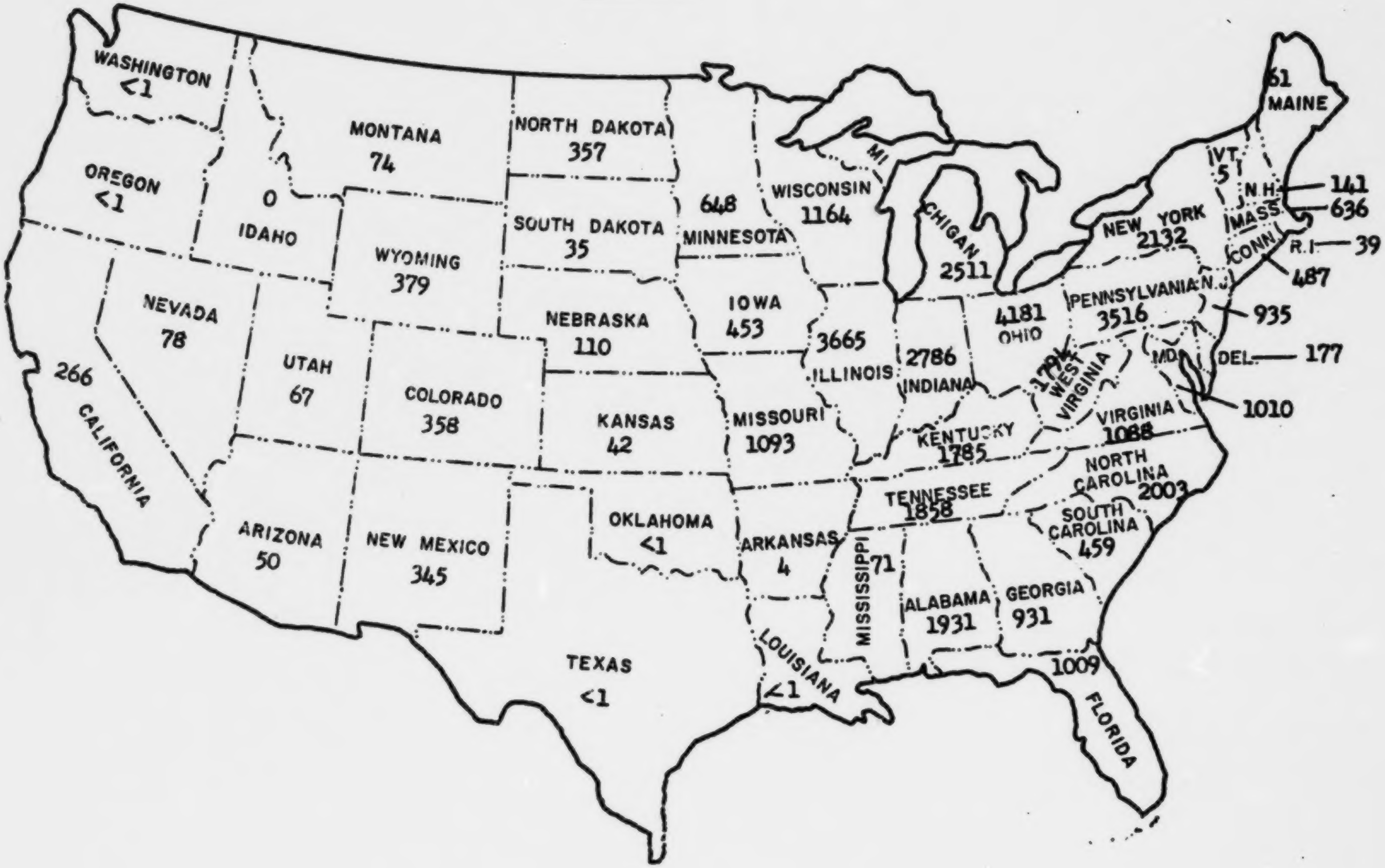
These are reasonable assumptions representing average values which were used to convert all consumption data to a uniform basis. They may or may not apply in any one particular case.

Based on these data and assumptions, the total amount of sulfur emitted to the atmosphere by power plants in 1969 amounted to almost 10 million tons, equivalent to about 20 million tons of SO_2. This converts to a potential demand of almost 41 million tons of limestone.

Figure 3 shows the potential limestone demand by state. Ohio ranks first in annual limestone requirements with over 4 million tons. The states east of the Mississippi River account for about 90% of the total limestone. Only one state west of the Mississippi River, Missouri, has a potential demand exceeding one million tons.

Table 4 itemizes potential demand by region. The East North Central region far outranks any other region in potential limestone requirements with over one-third of the national total requirement.

FIGURE 3


WASHINGTON <1
OREGON <1
CALIFORNIA 266
IDAHO 0
NEVADA 78
MONTANA 74
WYOMING 379
UTAH 67
ARIZONA 50
COLORADO 358
NEW MEXICO 345
NORTH DAKOTA 357
SOUTH DAKOTA 35
NEBRASKA 110
KANSAS 42
OKLAHOMA <1
TEXAS <1
MINNESOTA 648
IOWA 453
MISSOURI 1093
ARKANSAS 4
LOUISIANA <1
WISCONSIN 1164
ILLINOIS 3665
MISSISSIPPI 71
MI
CHIGAN 2511
INDIANA 2786
KENTUCKY 1785
TENNESSEE 1858
ALABAMA 1931
OHIO 4181
WEST VIRGINIA 1794
GEORGIA 931
FLORIDA 1009
PENNSYLVANIA 3516
VIRGINIA 1088
NORTH CAROLINA 2003
SOUTH CAROLINA 459
NEW YORK 2132
N.J. 935
MD 1010
DEL. 177
VT. 5
N.H. 141
MASS. 636
CONN. 487
R.I. 39
MAINE 61

POTENTIAL LIMESTONE DEMAND BY POWER PLANTS (BY STATE)

(M TONS)

TABLE 4

POTENTIAL LIMESTONE DEMAND BY POWER PLANTS IN THE UNITED STATES(1)

Region	Limestone (M Tons)	% of Total
New England	1,369	3.4
Middle Atlantic	6,583	16.2
East North Central	14,307	35.1
West North Central	2,738	6.7
South Atlantic	8,471	20.8
East South Central	5,645	13.9
West South Central	5	-
Mountain	1,351	3.3
Pacific	266	0.6
Total	40,735	100.0

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(1) See Section VID for explanation

VII. CARBONATE STONE RESOURCES

A. National Resources

1. All Types

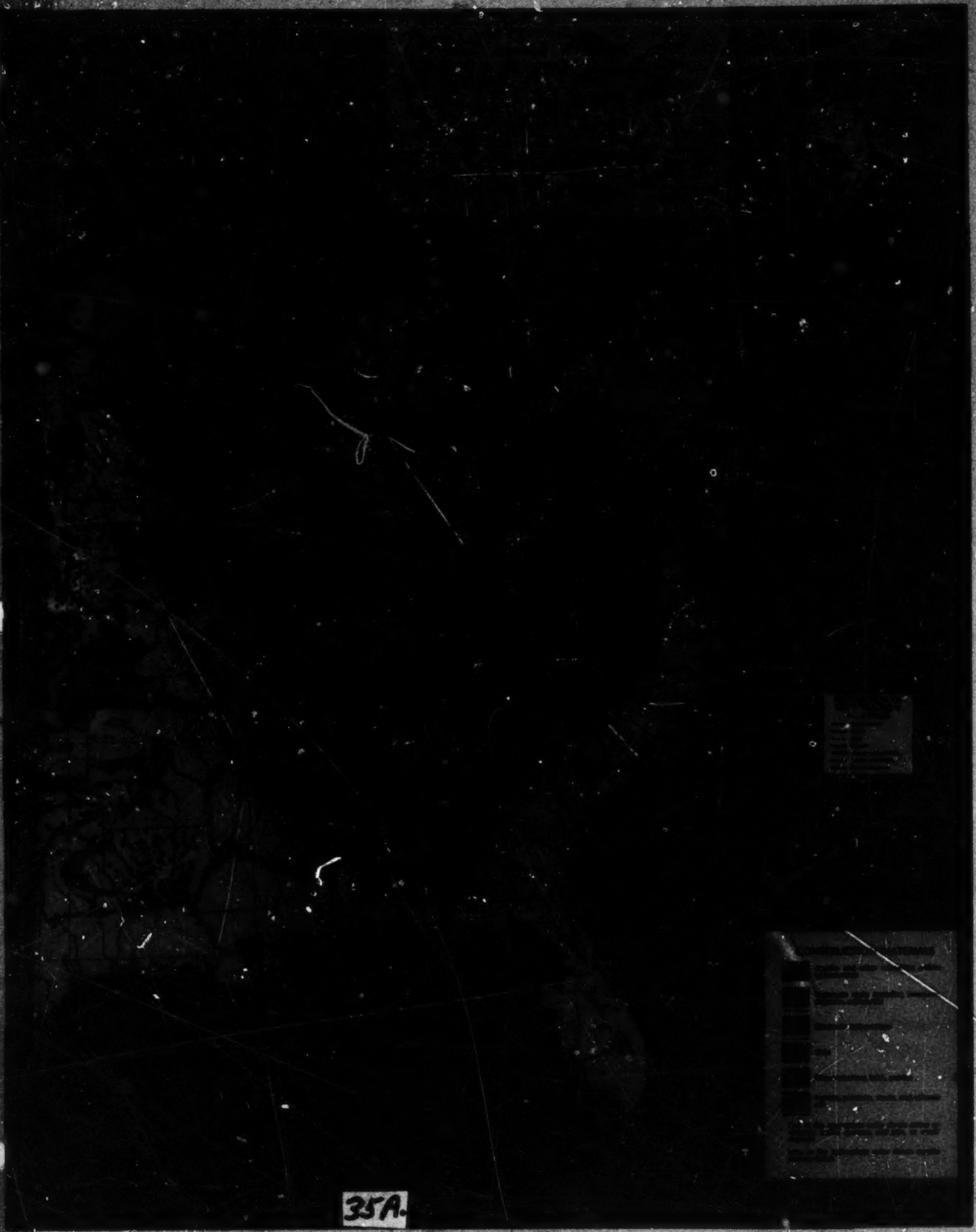
At least one form of carbonate rock, which includes limestone, dolomite, marble, marl and shell, is found in every state in the United States. Indeed, if all geologic rock stratus which contain carbonate stones of any type and purity were considered, the resultant map would indicate that virtually the entire country is underlain with these materials.

Such a depiction, however, would be misleading and certainly of little value in locating useful rock deposits. For example, carbonate stone which is burried under a thick layer of non-carbonate rock or other type of overburden is ordinarily of limited, if any, commercial value since the cost of extraction would be exceedingly high. Consequently, the discussion will be restricted to the more important deposits and outcrops.

Some states, such as Virginia, are fortunate in having useful reserves of all types of carbonate stones. Others, e.g., North Dakota, have very limited resources.

Figure 4 shows the distribution of carbonate rocks in the United States. It includes limestone, dolomite, and marble. The green-shaded areas indicate regions where the surface rock is predominantly carbonate. Green dots indicate quarries, and where they are shown outside of the areas of surface carbonate rock, mean that these rocks are inter-bedded with non-carbonate types and that quarrying occurs in selected beds of limestone, dolomite or marble.

35



35A.

The map shows that surface deposits of carbonate rocks occur throughout the nation, but are particularly in evidence in the eastern half of the country. A band of deposits beginning in Vermont extends southward along the Appalachian Mountains into central Alabama. Extensive deposits are found in the states surrounding the Great Lakes, reaching southward into northern Alabama. Large areas of Minnesota, Iowa, and Missouri are covered with carbonate rocks and broad outcrops occur in Kansas, Oklahoma, Arkansas, and Texas.

Particularly in the central lowlands, carbonate rock deposits frequently occur as thick, horizontal formations covering large areas. In general, the deposits found in western states are different. They commonly occur as steeply dipping or vertical beds of small areal extent. However, notable exceptions to this are found, particularly in Colorado, Arizona, and New Mexico where large outcrops occur.

Though not shown on the map, shell deposits occur in many coastal bay waters. They are particularly plentiful along the Gulf Coast, but important deposits also exist in California bays and in coastal waters in some southeastern states. Marls occur in several places throughout the country, but chiefly in the coastal plain of the southeastern states and in a large area of southwestern Michigan and northeastern Indiana. It varies considerably in character, that of the Great Lakes area being a precipitated calcium carbonate, while that of the coastal plain is an impure shell deposit.

National or regional reserves of carbonate rocks have never been determined. Although certain grades or purities may be limited in amount, the total limestone and dolomite resources are enormous. An estimate of reserves of surface carbonate rocks may be obtained by considering Figure 4, which shows approximately 316,000 square miles of carbonate deposits. Since the figure shows areas in which carbonate rocks predominate at the surface, it can be assumed that at least 50% of the surface rock is carbonate. If it is further assumed that the average thickness of all deposits shown is, say, 10 feet (a reasonable, and probably conservative value), and the rock has an average density of 165 lb/cu.ft., the total deposits amount to 3.63 x 10^{11} tons. Of this, approximately 2/3 occurs in the eastern half of the country, with about 1/2 of this latter amount found in the huge deposits in the Great Lake states south to northern Tennessee.

It should be emphasized that these estimates of reserves are very approximate, and ignore several factors. For example, carbonate rocks imbedded in other rock types or lying below the surface were not included. On the other hand, no distinction was made between usable and unusable reserves. Obviously, not all reserves are commercially workable. However, the estimates should give the reader an appreciation of the enormity of carbonate rock resources in the United States.

Many states have detailed maps and highly descriptive accounts of the carbonate rock deposits within the state. These may be obtained from the state geological surveys or equivalent organizations. For the reader who is interested in very specific information, a list of these organizations, giving names and mailing addresses, is given in Appendix B. Appendix A, which is a tabulation by county and state of working quarries for all carbonate rocks, is also provided.

2. Limestone

Limestone occurrences, including chalk but excluding dolomite, are shown in Figure 5. The map is similar to Figure 4 and shows that although limestone is found throughout the country, the more numerous and extensive deposits occur in the eastern half of the nation. In the western states, the deposits tend to be discontinuous and relatively small in areal extent.

Not all of the formations shown in Figure 5 qualify as high purity limestone. In fact, Boynton(1) estimates that only about 2% of the known reserves of commercially usable limestone are chemical grade (>95% carbonate content). Most stone of this type occurs in deposits in central and eastern states. Specific locations will be noted in the subsequent discussion of state-wide deposits, but much of the high purity limestone occurs in an area extending from the Great Lakes southward to Alabama.

Chalk deposits are shown in several of the central states and in a curving belt through Alabama and Mississippi. In general they are not high purity limestones, but locally they may contain over 95% calcium carbonate.

Coral limestone occurs in southern Florida. It is a high purity limestone which forms the foundation for the Florida Keys. Shell limestone which occurs along the Gulf Coast and in other coastal areas is also a high calcium stone.

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(1) Boynton, Robert S., Chemistry and Technology of Lime and Limestone, John Wiley & Sons, New York, 1966, p. 14.

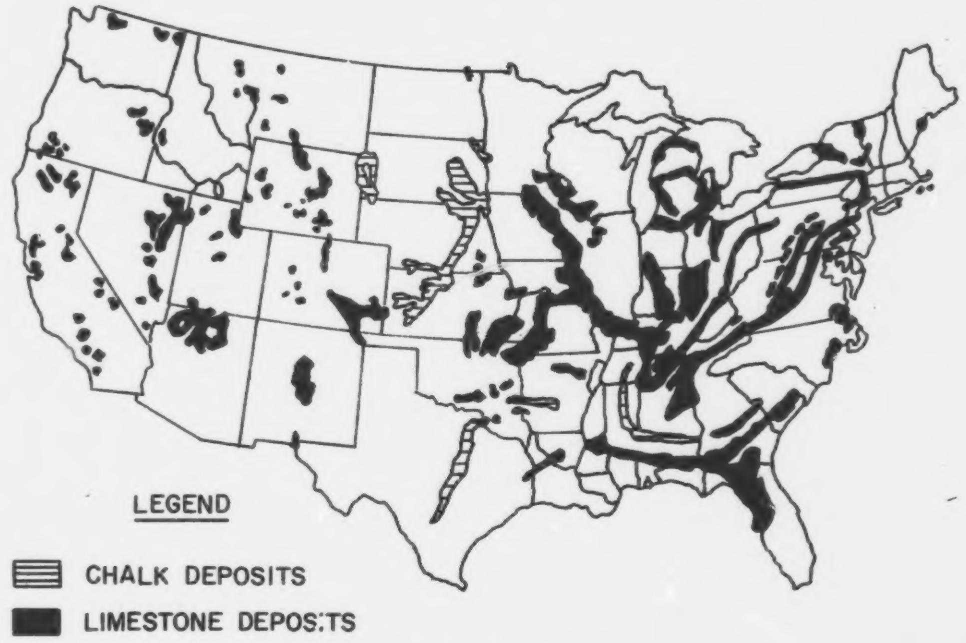

LEGEND
▤ CHALK DEPOSITS
■ LIMESTONE DEPOSITS

FIGURE 5

DISTRIBUTION OF CHALK AND LIMESTONE DEPOSITS IN THE UNITED STATES

(REPRINTED FROM U.S. BUREAU OF MINES BULLETIN NO. 395)

Naturally occurring calcium carbonate exists in two forms: calcite and aragonite. The rhombohedral form, calcite, is by far the more common and more stable crystalline type. Orthorhombic aragonite alters irreversibly to calcite. Aragonite is the common form chiefly where precipitation of calcium carbonate from warm waters has occurred, e.g., coral reefs in tropical waters or deposits from hot springs.

3. Dolomite

Figure 6 shows the location of high grade (>25% magnesium carbonate) dolomite quarries. Although originally drawn in 1941, it is a useful guide to the important occurrences of dolomite. As with limestone, the largest deposits are located in the eastern half of the country. Two major areas are noted. First, a belt of dolomite extends from Vermont to central Alabama, along the Appalachian Mountains. This coincides quite well with a similar band of limestone previously noted. Second, large formations of dolomite occur in the states encircling the Great Lakes. These deposits coincide with or adjoin large limestone deposits in the region.

Since the major deposits of both limestone and dolomite are located in approximately the same areas, it could be anticipated that stones of intermediate composition would exist. This, in fact, does occur, and gradations ranging from a high calcium limestone to a high purity dolomite are commonly found in the same locality. However, the nature and extent of this type of occurrence is difficult to predict. Limestone and dolomite may occur in adjacent or overlaying deposits or they may be interbedded within one formation. Frequently, the stone will vary in composition in the horizontal or vertical direction or both. To determine the nature of the deposit, core sampling is employed.

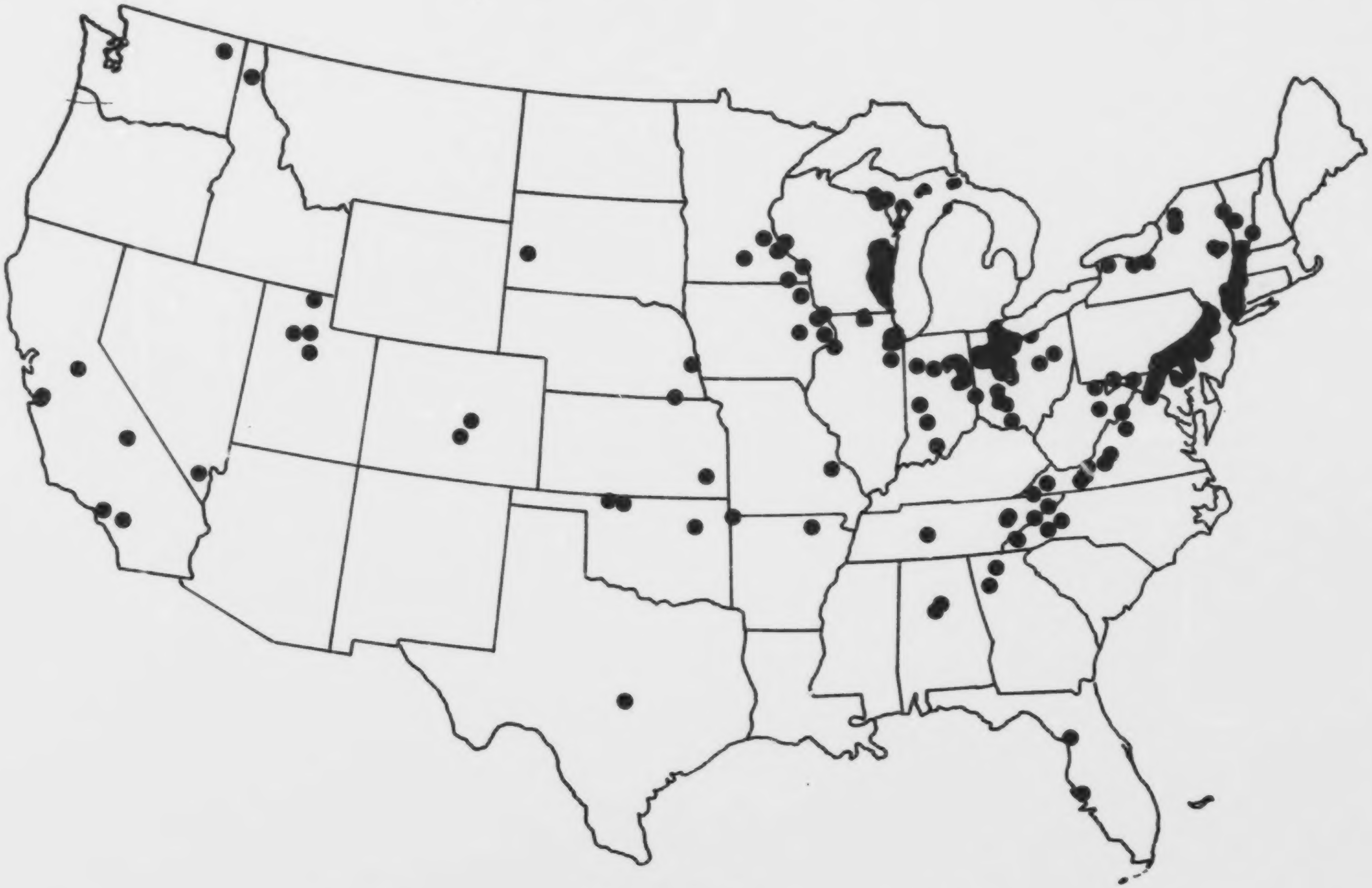


FIGURE 6

LOCATION OF HIGH-GRADE DOLOMITE QUARRIES IN THE UNITED STATES

(REPRINTED FROM U.S. BUREAU OF MINES INFORMATION CIRCULAR NO. 7192)

4. Marble

Marble deposits in the United States occur chiefly in mountainous regions where intense folding has produced a compact, highly crystalline stone from the original limestone or dolomite. In this country, most marble is of the high calcium type.

The most productive marble belt is shown in Figure 7. It extends from the Canadian border in northern Vermont southward to southeastern New York. Beginning again in western New Jersey, it follows a fairly narrow path through the Appalachian Mountains before ending in Alabama. A few deposits are dolomitic, but high calcium stone greatly predominates, occurring in thick beds.

Important marble belts also occur in the Rocky Mountains and Coast Ranges of the west, particularly in the southwestern region. Deposits are numerous, but many are too small or inaccessible to be of commercial importance. Marble occurrences are also found in isolated deposits in some central states.

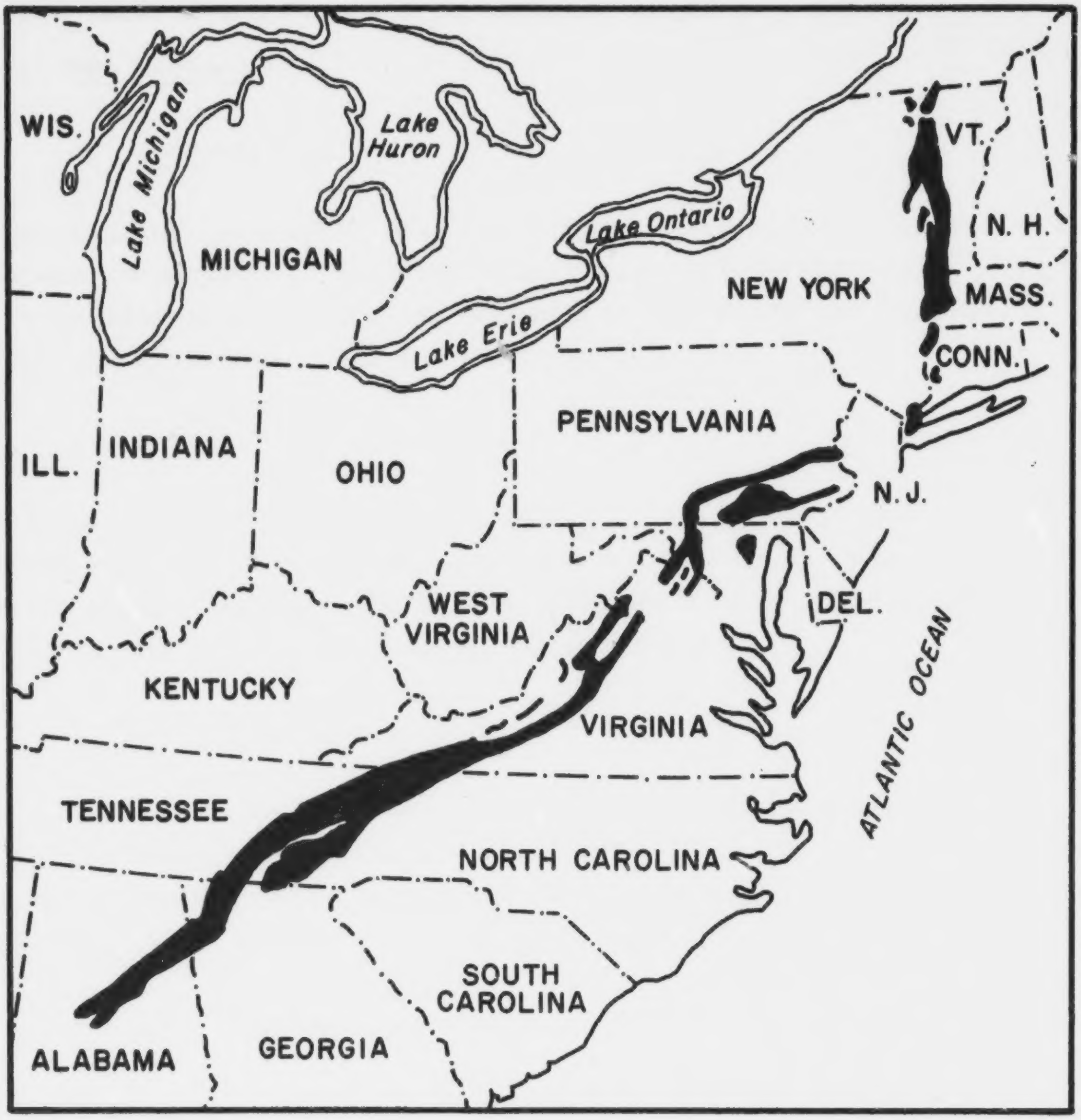

WIS.
Lake Michigan
MICHIGAN
Lake Huron
Lake Ontario
Lake Erie
NEW YORK
VT.
N. H.
MASS.
CONN.
PENNSYLVANIA
N. J.
DEL.
ILL.
INDIANA
OHIO
WEST VIRGINIA
KENTUCKY
VIRGINIA
ATLANTIC OCEAN
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ALABAMA
GEORGIA

FIGURE 7

MARBLE DEPOSITS IN THE EASTERN UNITED STATES

(REPRINTED FROM U.S. BUREAU OF MINES INFORMATION CIRCULAR NO. 7829)

B. Regional Resources

(See Table 5 and Figure 8 for typical chemical analyses.)

1. New England

a. Connecticut

Deposits of carbonate rocks are found in the border counties of western Connecticut. They are highly crystalline and occur chiefly as magnesian limestones, dolomites, and dolomitic marbles. Outcrops are frequently high grade stone.

b. Maine

Steeply dipping beds of hard, crystalline, high calcium limestone occur in southern Maine around Knox County. High grade dolomitic stones also are found. In northern Maine, a noncrystalline high grade limestone outcrops in Aroostook County.

c. Massachusetts

Crystalline limestones and dolomites occur in Berkshire County in western Massachusetts. High grade outcrops of both types are present. Some dolomitic marble also occurs in the region.

d. New Hampshire

No commercially important outcrops of limestone or dolomite occur in New Hampshire.

e. Rhode Island

High calcium limestone outcrops only in Providence County in northern Rhode Island.

TABLE 5

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS - NEW ENGLAND REGION

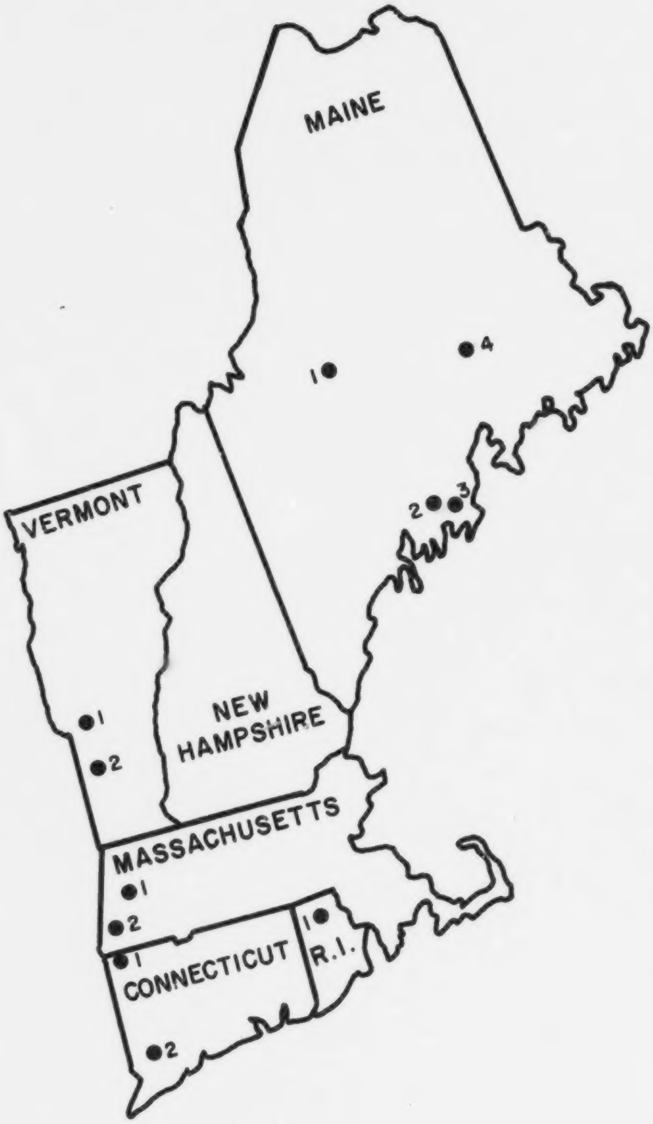
<table>
<tr><th rowspan="2">State</th><th rowspan="2">Sample No.(1)</th><th colspan="6">Chemical Composition (weight%)</th></tr>
<tr><th>$CaCO_3$</th><th>$MgCO_3$</th><th>SiO_2</th><th>Al_2O_3</th><th>Fe_2O_3</th><th>Other</th></tr>
<tr><td>Connecticut</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>54.37</td><td>44.94</td><td>0.08</td><td colspan="2">←←←←0.25→→→</td><td></td></tr>
<tr><td></td><td>2</td><td>89.96</td><td>0.21</td><td>5.83</td><td colspan="2">←←←←3.90→→→</td><td></td></tr>
<tr><td>Maine</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>73.8</td><td></td><td>24.8</td><td></td><td>1.4</td><td></td></tr>
<tr><td></td><td>2</td><td>53.13</td><td>42.94</td><td>2.87</td><td colspan="2">←←←←1.06→→→</td><td></td></tr>
<tr><td></td><td>3</td><td>97.69</td><td>0.82</td><td>0.43</td><td>0.71</td><td>0.25</td><td></td></tr>
<tr><td></td><td>4</td><td>89.2</td><td></td><td>9.6</td><td></td><td>1.2</td><td></td></tr>
<tr><td>Massachusetts</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>93.86</td><td>5.34</td><td>0.69</td><td colspan="2">←←←←0.06→→→</td><td></td></tr>
<tr><td></td><td>2</td><td>58.77</td><td>40.34</td><td>0.39</td><td colspan="2">←←←←0.16→→→</td><td></td></tr>
<tr><td>Rhode Island</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>88.23</td><td>8.80</td><td>2.75</td><td>0.31</td><td>0.01</td><td></td></tr>
<tr><td>Vermont</td><td>1</td><td>99.71</td><td>0.71</td><td></td><td>0.06</td><td>0.02</td><td></td></tr>
<tr><td></td><td>2</td><td>98.71</td><td>0.86</td><td></td><td>0.10</td><td>0.03</td><td></td></tr>
</table>

(1) Sample numbers correspond to those shown on Figure 8.

FIGURE 8

SAMPLE LOCATIONS OF CARBONATE ROCKS

NEW ENGLAND REGION


MAINE
1
4
2
3
VERMONT
1
2
NEW HAMPSHIRE
MASSACHUSETTS
1
2
CONNECTICUT
1
2
R.I.
1

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 5)

f. Vermont

Carbonate deposits in Vermont range from the noncrystalline limestones found in the northwestern counties to the highly crystalline calcitic marbles of Rutland County. High calcium limestones and marbles outcrop chiefly throughout the western tier of counties. High grade dolomitic stone is found in central to southern Vermont.

2. Middle Atlantic

(See Table 6 and Figure 9 for typical chemical analyses.)

a. New York

New York has extensive deposits of limestone and dolomitie Limestone crops out in a band which spreads eastward from Lake Erie to Albany County, then curving south through Orange County. Another formation, containing stone of 95% or more calcium carbonate, extends northward from Saratoga County through the eastern Adirondacks to the Canadian border. A large outcrop of limestone occurs along the east shore of Lake Ontario and extends southeast in a narrow belt to Montgomery County. Dolomite outcrops in a narrowing band stretching eastward from Niagara to Oneida County. Crystalline dolomite of high purity is found extensively in the northern areas of St. Lawrence and Franklin Counties. Dolomitic marbles occur in southeastern New York, especially along the Connecticut and Massachusetts borders.

High calcium limestones are abundant in New York, particularly in the western half of the state.

b. New Jersey

Carbonate rock deposits exist in the northwestern counties of the state. Dolomite and magnesian limestone occur in Sussex, Warren, Somerset, and Hunterdon Counties. A crystalline limestone occurs in Sussex and Warren Counties and varies in composition from nearly pure calcium carbonate to dolomite.

c. Pennsylvania

Enormous quantities of carbonate rocks occur throughout central and southern Pennsylvania and much of this is high grade stone. High purity dolomites can be found in the southeastern counties and in a belt reaching southwestward from Northampton County to Franklin County. Extensive deposits of high-calcium

TABLE 6

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS-MIDDLE ATLANTIC REGION

<table>
<tr><th>State</th><th>Sample No.(1)</th><th colspan="6">Chemical Composition (weight %)</th></tr>
<tr><th></th><th></th><th>$CaCO_3$</th><th>$MgCO_3$</th><th>SiO_2</th><th>Al_2O_3</th><th>Fe_2O_3</th><th>Other</th></tr>
<tr><td>New Jersey</td><td>1</td><td>77.9</td><td>14.6</td><td>6.7</td><td>1.2</td><td>0.4</td><td></td></tr>
<tr><td></td><td>2</td><td>52.8</td><td>41.8</td><td>2.3</td><td colspan="2">←←←←←←1.4→→→→→→→</td><td></td></tr>
<tr><td></td><td>3</td><td>57.8</td><td>32.4</td><td>2.0</td><td colspan="2">←←←←←←8.4→→→→→→→</td><td></td></tr>
<tr><td>New York</td><td>1</td><td>55.45</td><td>44.06</td><td colspan="4">←←←←←←←←<2.0→→→→→→→→→→→→</td></tr>
<tr><td></td><td>2</td><td>94.78</td><td>1.46</td><td>1.2</td><td>0.3</td><td>1.0</td><td>2.22</td></tr>
<tr><td>Pennsylvania</td><td>1</td><td>74.26</td><td>4.08</td><td>12.66</td><td>5.19</td><td>1.87</td><td></td></tr>
<tr><td></td><td>2</td><td>55.23</td><td>43.22</td><td>0.65</td><td colspan="2">←←←←←←0.92→→→→→</td><td></td></tr>
<tr><td></td><td>3</td><td>96.45</td><td>1.99</td><td>1.30</td><td colspan="2">←←←←←←0.26→→→→→</td><td></td></tr>
</table>

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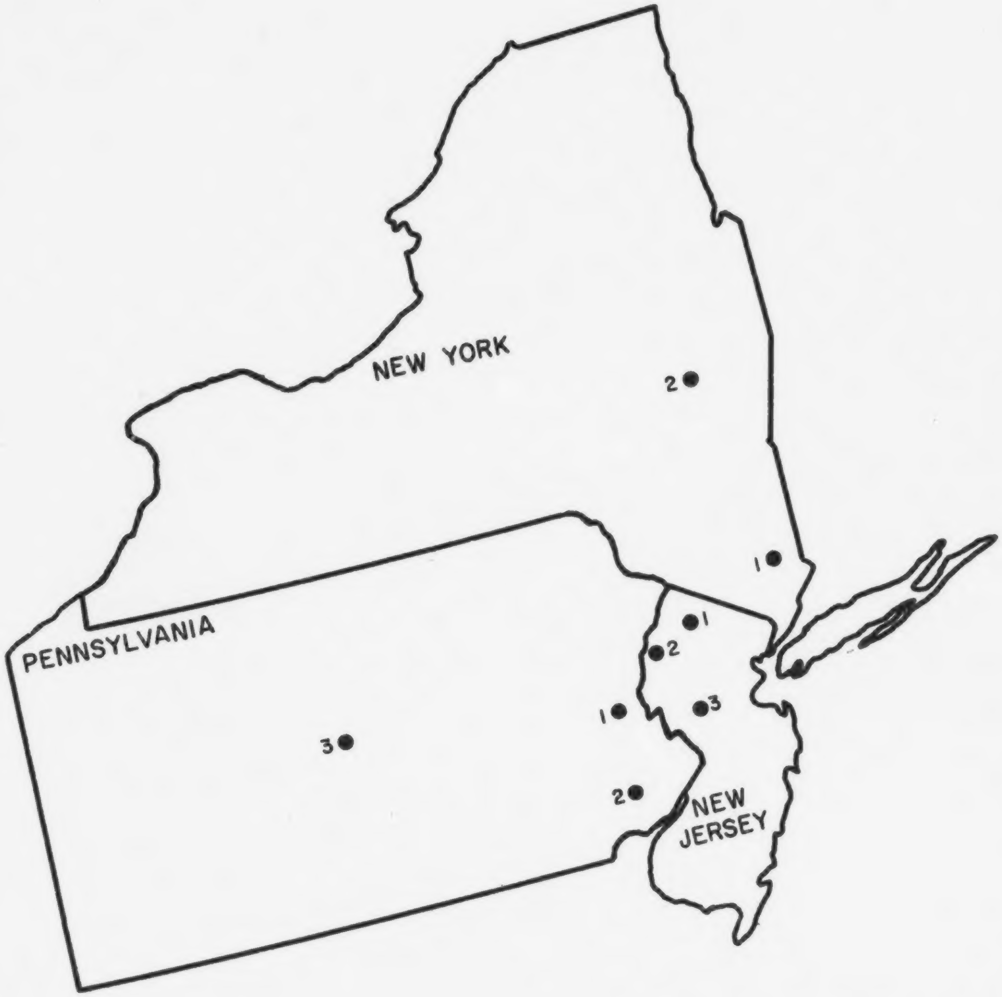
(1) Sample numbers correspond to those shown on Figure 9.

FIGURE 9

SAMPLE LOCATIONS OF CARBONATE ROCKS

MIDDLE ATLANTIC REGION


NEW YORK
2
1
PENNSYLVANIA
3
1
2
1
2
3
NEW JERSEY

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 6)

limestone occur in the southeastern region, in the central and south central region, and in a large area north of Pittsburgh. The most important high purity limestone deposits occur as thin, curving bands in central Pennsylvania. Most of the large western deposit does not outcrop.

An argillaceous limestone appears abundantly as a narrow belt through Berks, Lehigh, and Northampton Counties. In north central and western Pennsylvania, carboniferous limestones are widespread.

3. East North Central

(See Table 7 and Figure 10 for typical chemical analyses.)

a. Illinois

Illinois has large reserves of good quality limestone and dolomite occurring in thick, massive beds. A vast outcrop of dolomite covers much of the northern quarter of Illinois and, particularly in the northeastern counties, is a very pure stone. Large deposits of limestone occur in western and southwestern Illinois, and in the extreme southern tip of the state. They contain abundant reserves of high calcium stone.

Other smaller deposits of limestone occur in outcrops scattered throughout the state. These beds are generally much thinner than those of western and northern Illinois. Dolomitic stone is found also in southwestern Illinois.

b. Indiana

Indiana contains large deposits of carbonate rocks. The chief source of high-calcium limestone occurs in a deposit stretching from the Ohio River on the south-central border northwestward to Montgomery County. This deposit contains extensive amounts of high grade limestone.

A large outcrop of dolomite occurs in east-central Indiana and extends into the northwestern counties. It is bordered on the western and northern sides by deposits of limestone. These deposits contain many occurrences of high grade limestones and dolomites. However, they frequently outcrop in thin beds.

A soft, calcareous marl occurs in the north-central and northeastern counties.

TABLE 7

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS EAST NORTH CENTRAL REGION

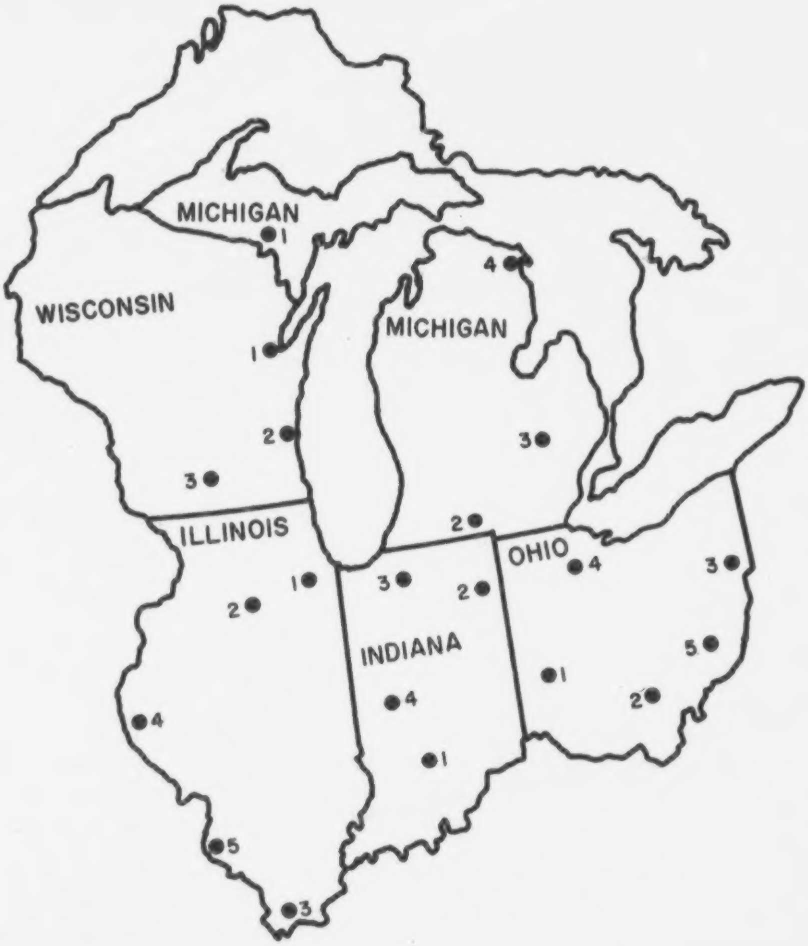
State	Sample No.(1)	Chemical Composition (weight %)					
		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
Illinois	1	47.70	40.71	7.96	1.97	0.70	2.27
	2	85.39	1.38	6.72	5.92		
	3	98.19	1.17	0.65	1.43	0.09	
	4	98.46	1.95	0.42	0.42	0.13	
	5	95.73	3.45	0.08	0.74		
Indiana	1	97.82	1.51		0.55	0.15	0.03
	2	54.9	43.9	0.62	0.15	0.22	0.14
	3	96.3	3.1	0.17	0.03	0.17	0.09
	4	95.7	0.96	2.55	0.27	0.25	0.08
Michigan	1	55.28	42.84	0.73	0.20	1.03	0.05
	2	92.25	2.87	0.52	0.51	0.53	0.36
	3	92.09	3.52	0.90	0.20	0.39	0.18
	4	96.92	1.46	1.46	0.54		
Ohio	1	92.16	5.73	0.56	0.45	0.20	0.75
	2	91.12	0.92	1.90	1.06	3.11	1.04
	3	68.45	2.76	13.80	7.00	4.55	4.01
	4	53.91	45.44	0.14	0.05	0.12	TR
	5	95.93	1.15	4.82	0.47		0.10
Wisconsin	1	49.47	44.58	3.17	1.95		
	2	52.29	42.27	3.96	1.68		
	3	84.02	5.33	7.03	2.21	1.22	

(1) Sample numbers correspond to those shown on Figure 10.

FIGURE 10

SAMPLE LOCATIONS OF CARBONATE ROCKS

EAST NORTH CENTRAL REGION


MICHIGAN
1
WISCONSIN
1
2
3
MICHIGAN
4
3
2
ILLINOIS
1
2
4
5
3
INDIANA
3
2
4
1
OHIO
4
3
5
1
2

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 7)

c. Michigan

Michigan contains large reserves of carbonate rocks, most of which occur in the northern part of the state. In the southern part of the Upper Peninsula the stone is largely dolomitic. However, both high calcium limestone and high grade dolomite occur, in a curving belt running eastward from Delta County.

Extensive deposits of limestone are found in an east-west band through the northern part of the Southern Peninsula. Large amounts of high calcium limestone exist and outcrop in the eastern part of the band as broad, thick beds.

Locally high grade limestone and dolomite occur in southeastern Michigan. Important limestone deposits also can be found in an area near Saginaw Bay. The southwestern counties contain large amounts of calcareous marl.

d. Ohio

Huge reserves of limestone and dolomite exist in Ohio in deposits located throughout the state. The more important formations are in the western half of the state, however, and these outcrop in large, thick beds.

Abundant deposits of dolomite occur in western Ohio, with an exceptionally pure dolomite outcropping in the Toledo region. Another broad area of dolomite extends from the Indiana border in west-central Ohio south to Adams County. Good quality dolomites and magnesian limestones are found. A north-south belt of limestone, beginning around Sandusky and extending to the Columbus region, has abundant deposits of high-calcium stone. A curving band of limestone can also be found in the northwestern corner of Ohio. High grade limestones occur locally in eastern Ohio, but the outcrops are generally thin.

e. Wisconsin

Nearly all of the large carbonate rock resources of Wisconsin are dolomites or magnesian limestone. The most important dolomite deposits appear as a broad north-south band along the eastern border of the state. Much of this stone is high purity. Other deposits of generally inferior stone are scattered throughout the southern and western counties.

4. West North Central

(See Table 8 and Figure 11 for typical chemical analyses.)

a. Iowa

Carbonate rocks are abundant in Iowa, with most of the reserves occurring in the eastern half of the state. The most important deposits are found in a band extending from the north central border region southeastward to the Davenport area. High calcium stones outcrop chiefly in the north central and far southeastern parts of this band. Dolomitic formations are exposed intermittently in northeastern and east central counties, with high grade stone appearing chiefly in the area around Linn County. Chalk, locally of high calcium content, appears in northwestern Iowa.

b. Kansas

Limestone deposits underlay the eastern third of Kansas. Most of the stone is fairly pure, above 87% calcium carbonate, and locally it is of high purity. High grade limestones are generally restricted to extreme eastern Kansas, particuarly in the Kansas City area and the southeastern counties. Dolomites are found in south central and southwestern regions and, though not high grade, are fairly pure. Chalk occurs in an irregular band extending from Jewell County in north central Kansas southwestward to Finney County. Although locally it may be high calcium material, it is covered frequently with large beds of shale. Marl deposits are found in the western counties of Wallace and Logan.

c. Minnesota

Deposits of carbonate rocks cover much of the southeastern corner of Minnesota. Most of the stone is magnesian limestone or dolomite. However, in addition to high-purity dolomite, high calcium limestone is also found. A small area of chalk occurs in extreme western Minnesota, in the region of Lac qui Parle County. Marl exists in the central part of the state.

TABLE 8

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS
WEST NORTH CENTRAL REGION

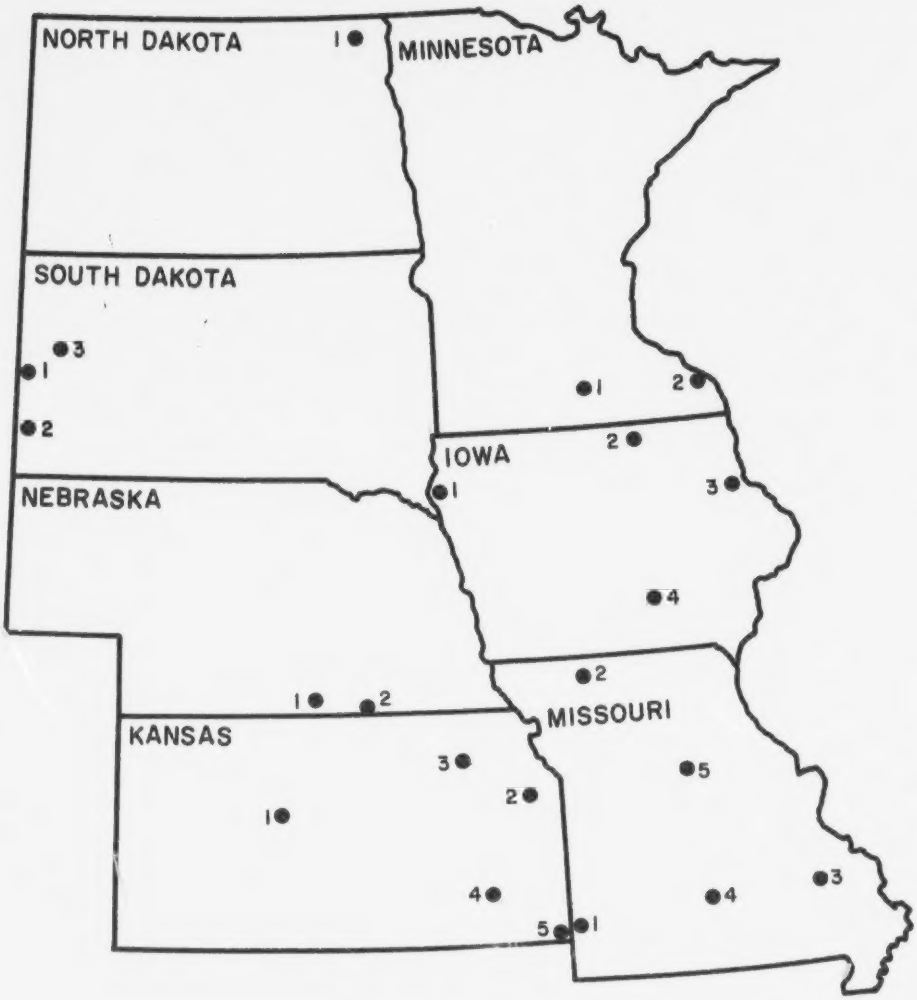
<table>
<tr><th>State</th><th>Sample No.(1)</th><th colspan="6">Chemical Composition (weight %)</th></tr>
<tr><th></th><th></th><th>$CaCO_3$</th><th>$MgCO_3$</th><th>SiO_2</th><th>Al_2O_3</th><th>Fe_2O_3</th><th>Other</th></tr>
<tr><td>Iowa</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>92.1</td><td>3.1</td><td>1.4</td><td>0.9</td><td>0.2</td><td></td></tr>
<tr><td></td><td>2</td><td>98.01</td><td>0.15</td><td>0.78</td><td>0.12</td><td></td><td>0.29</td></tr>
<tr><td></td><td>3</td><td>90.20</td><td>2.65</td><td>3.26</td><td colspan="2">←←←←0.83→→→→</td><td>2.56</td></tr>
<tr><td></td><td>4</td><td>95.30</td><td></td><td>4.01</td><td>0.13</td><td>0.46</td><td></td></tr>
<tr><td>Kansas</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>93.68</td><td>1.23</td><td>2.38</td><td>1.57</td><td>0.56</td><td></td></tr>
<tr><td></td><td>2</td><td>68.90</td><td>19.64</td><td>3.22</td><td>0.61</td><td>5.10</td><td></td></tr>
<tr><td></td><td>3</td><td>92.98</td><td>1.57</td><td>3.27</td><td>0.44</td><td>0.71</td><td>0.20</td></tr>
<tr><td></td><td>4</td><td>92.98</td><td>1.99</td><td>3.64</td><td>1.50</td><td>1.21</td><td>0.14</td></tr>
<tr><td></td><td>5</td><td>98.19</td><td>0.92</td><td>0.29</td><td>0.08</td><td>0.16</td><td>0.03</td></tr>
<tr><td>Minnesota</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>48.91</td><td>39.54</td><td colspan="2">←←←10.40→→→→</td><td>1.10</td><td></td></tr>
<tr><td></td><td>2</td><td>54.98</td><td>41.21</td><td colspan="2">←←← 3.20→→→→</td><td>0.60</td><td></td></tr>
<tr><td>Missouri</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>99.18</td><td>0.20</td><td>0.23</td><td>0.17</td><td>0.07</td><td></td></tr>
<tr><td></td><td>2</td><td>91.58</td><td>1.80</td><td>3.98</td><td>0.36</td><td>0.56</td><td></td></tr>
<tr><td></td><td>3</td><td>95.90</td><td>4.60</td><td>0.30</td><td>0.95</td><td>0.17</td><td></td></tr>
<tr><td></td><td>4</td><td>52.59</td><td>42.59</td><td>2.48</td><td>0.61</td><td>0.36</td><td></td></tr>
<tr><td></td><td>5</td><td>80.98</td><td>11.53</td><td>6.87</td><td colspan="2">←←←←0.62→→→→</td><td></td></tr>
<tr><td>Nebraska</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>80.9</td><td>1.7</td><td>6.9</td><td>3.3</td><td>1.0</td><td>4.6</td></tr>
<tr><td></td><td>2</td><td>95.7</td><td>0.8</td><td>1.5</td><td>1.8</td><td>0.4</td><td>0.73</td></tr>
<tr><td>North Dakota</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>66.6</td><td>2.1</td><td>14.7</td><td>7.1</td><td>1.7</td><td>6.5</td></tr>
<tr><td>South Dakota</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>96.35</td><td>3.43</td><td>0.56</td><td>0.06</td><td>0.20</td><td></td></tr>
<tr><td></td><td>2</td><td>97.21</td><td>1.00</td><td>1.22</td><td>0.34</td><td>0.44</td><td></td></tr>
<tr><td></td><td>3</td><td>69.35</td><td>2.26</td><td>15.51</td><td colspan="2">←←←←5.80→→→→</td><td></td></tr>
</table>

(1) Sample numbers correspond to those shown on Figure 11.

FIGURE 11

SAMPLE LOCATIONS OF CARBONATE ROCKS

WEST NORTH CENTRAL REGION


NORTH DAKOTA
1
MINNESOTA
1
2
SOUTH DAKOTA
3
1
2
IOWA
1
2
3
4
NEBRASKA
1
2
KANSAS
1
2
3
4
5
MISSOURI
1
2
3
4
5

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 8)

d. Missouri

Carbonate rocks are abundant and widely distributed throughout all of Missouri. An argillaceous limestone covers a large area in the south central part of the state. High calcium limestone outcrops frequently in thick deposits west of the Mississippi River in eastern and southeastern counties. Southwestern Missouri also has large reserves of high calcium stone. Limestone occurs in central and northwestern parts in fairly thin beds which are locally of high grade rock. Cherty limestones and a siliceous dolomite are found in northeastern portions of the state.

Marble of the high calcium variety exists in southeastern Missouri. Deposits also occur in the southwestern counties of Jasper and Greene.

e. Nebraska

A wide belt of chalk extends from northeastern Nebraska southward to the south central border. The material is argillaceous and of variable composition, although in places it contains up to 96% calcium carbonate. A small exposure of chalk is found also in the extreme northwestern part of the state. Deposits in the southeastern corner of Nebraska contain high calcium limestone and high purity dolomite.

f. North Dakota

An argillaceous limestone occurs in the northern part of North Dakota as a soft, chalky rock. Small reserves also are present in the southwestern region in the form of thin, cherty beds.

g. South Dakota

A variety of carbonate rocks occur in South Dakota in good quantities. The largest and most important deposits are located in the southwestern region of the Black Hills and contain virtually all of the high quality stone in the state. Elliptical belts of stone which occur in this region have outcrops of dolomitic marble in addition to high grade dolomite and high calcium limestone. A long, narrow band of chalky shale surrounds the Black Hills. The chalk also outcrops extensively in several southeastern counties and though of a better quality than the southwestern formation, is generally impure and siliceous. In isolated areas, exposures of high calcium stone are found.

5. South Atlantic

(See Table 9 and Figure 12 for typical chemical analyses.)

a. Delaware

In extreme northern Delaware, a dense, crystalline stone, which is mostly dolomitic but with variable magnesium content, outcrops in two small areas.

b. Florida

Limestones are plentiful in Florida, and many of them are soft, shell types. One of the most important is an extensive deposit which outcrops in Levy County and several surrounding counties in the west central part of the peninsula. It is a soft, very pure stone which has analyzed as high as 99.6% calcium carbonate. Directly to the south, principally in Hernando and Pasco Counties, lies a generally hard, somewhat siliceous limestone occurring in small, discontinuous lenses.

An oolitic limestone which is generally siliceous covers the southeastern tip of Florida. Coral and oolitic limestones form the foundation for the Keys. A siliceous, coquina limestone is found in many places along the eastern coast, while a harder limestone outcrops in various places in western Florida, particularly in Jackson County.

A calcareous marl covers much of the southern half of the peninsula. Shell deposits occur chiefly in the bay waters near Walton County and in the Tampa and Fort Meyers areas.

c. Georgia

The extensive deposits of carbonate rocks in Georgia occur chiefly in two areas. A wide band of limestone, dolomite, and marble cuts through the northwestern corner of Georgia. Both

TABLE 9

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS

SOUTH ATLANTIC REGION

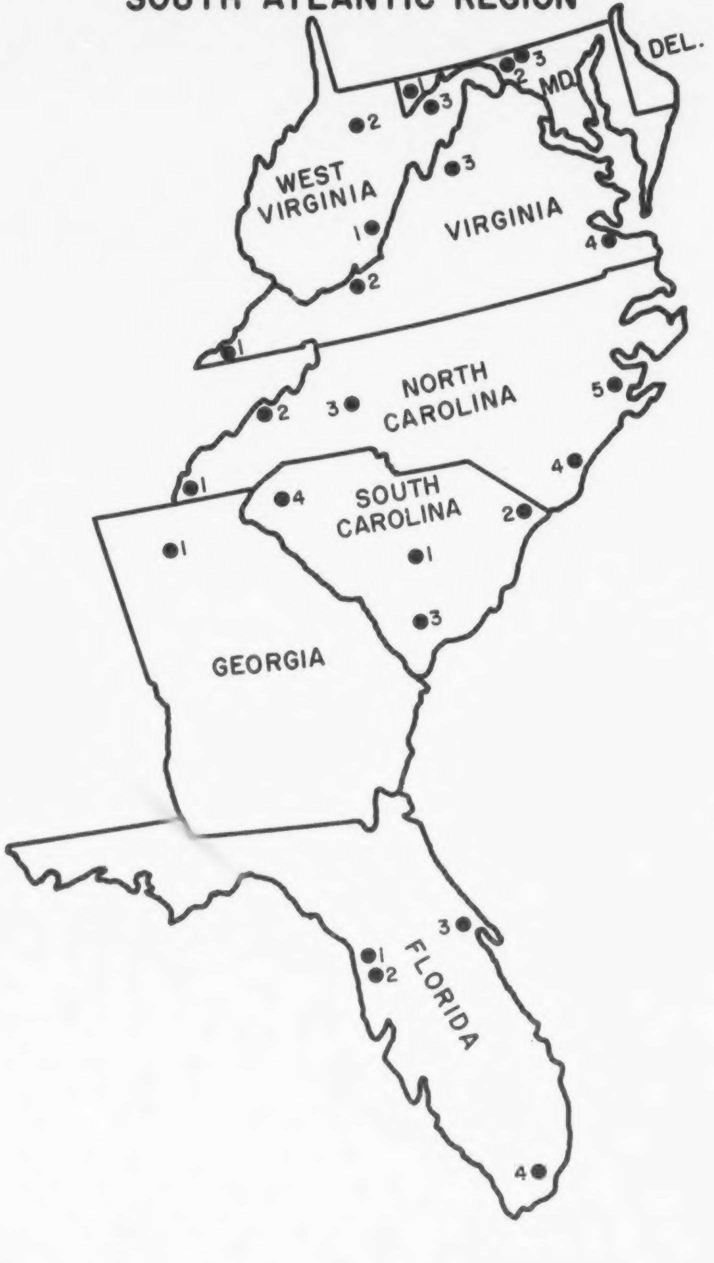
State	Sample No.(1)	Chemical Composition (weight %)					
		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
Florida							
	1	98.19	0.55	1.30			
	2	91.09	TR	6.54	←←←←←←2.39→→→→→→→		
	3	80.00		17.58	←←←←←←0.93→→→→→→→		
	4	70.98	0.30	28.66			
Georgia							
	1	96.13	1.90		0.65	0.23	
Maryland							
	1	88.73	0.86	8.57	←←←←←←2.38→→→→→→→		
	2	60.73	35.79	0.98	←←←←←←1.19→→→→→→→		
	3	95.55	4.39	0.68	←←←←←←0.51→→→→→→→		
North Carolina							
	1	57.21	36.13	2.93		0.56	
	2	97.28	0.88	1.60		0.09	
	3	59.23	39.89		1.28	3.17	
	4	89.47		5.52	0.68	1.05	2.26
	5	75.84	1.92	19.74	1.17	0.49	0.88
South Carolina							
	1	91.36	1.63	3.09	0.38	1.70	1.61
	2	57.67	3.95	33.32	0.95	0.63	4.53
	3	65.85	0.46	30.18	0.26	1.10	2.50
	4	90.56	TR	6.40		3.14	
Virginia							
	1	91.72	4.58	2.80	←←←←←←0.90→→→→→→→		
	2	86.61	3.91	8.24	←←←←←←1.04→→→→→→→		
	3	86.82	2.71	9.10	←←←←←←1.32→→→→→→→		
	4	80.00	1.01	11.42	2.68	4.10	
West Virginia							
	1	87.93	4.00	4.97	←←←←←←2.82→→→→→→→		
	2	95.52	1.88	0.92	←←←←←←0.96→→→→→→→		
	3	98.94	0.68	0.49	←←←←←←0.40→→→→→→→		

(1) Sample numbers correspond to those shown on Figure 12.

FIGURE 12

SAMPLE LOCATIONS OF CARBONATE ROCKS

SOUTH ATLANTIC REGION


DEL.
MD.
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
1
2
3
4
5

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 9)

high calcium limestone and high grade dolomite are found. A second area occurs as a broad band of limestone extending from the southwest corner of the state into central Georgia. It contains some outcrops of high calcium stone.

d. Maryland

Carbonate rocks outcrop in northern Maryland, chiefly in areas north and west of Baltimore. The larger deposits of limestone and dolomite occur in Washington and Frederick Counties and are the best source of high quality stone of both types. Thin bands of limestone, oriented southwest-northeast, are found in the western counties of Garret and Allegany. A large area in the center of Baltimore County is covered with a marble which varies from calcitic to dolomitic. Some high grade stone may be present.

e. North Carolina

Highly crystalline limestones and dolomites occur in western North Carolina primarily as thin, steeply dipping, isolated bands extending northeastward from the southern border. These marble formations vary in composition from calcitic to dolomitic and frequently contain over 95% total carbonates. Calcareous marls are abundant along the coastal plain of eastern North Carolina, but are generally poor to fair in quality. Occasional beds of high calcium limestone do occur, however.

f. South Carolina

South Carolina has deposits of highly crystalline limestone and dolomite occurring in thin, steeply dipping bands in the northwestern counties. The most abundant resources, however, are found in the coastal plains of southern and eastern South Carolina. A large limestone deposit exists in and around Orangeburg County. The stone is frequently of fairly good quality and in certain areas exceeds 97-98% calcium carbonate. Calcareous marls abound along the coastal plain, but most is poor to fair in calcium carbonate content.

g. Virginia

Large deposits of carbonate rocks occur in Virginia, chiefly in the western part of the state. Limestone and dolomite outcrop extensively in the two western tiers of counties extending from the north border to the south border. In many of these regions, high grade limestone or dolomite exists. Marble also occurs.

Marl is found on the coastal plain in southeastern Virginia. It is a soft, impure limestone which occurs in shallow beds.

h. West Virginia

Most of the deposits of carbonate rocks in West Virginia occur in the eastern border counties. A large limestone deposit exists in Monroe and Greenbrier counties and extends northeastward in narrow bands to the Maryland line. The stone is hard and relatively impure. The most important occurrences of carbonate rocks are located in the far eastern part of the state, in Berkeley and Jefferson Counties. Both high-calcium limestone and high purity dolomite outcrop. Beds extend northeast-southwest throughout both counties.

6. East South Central

(See Table 10 and Figure 13 for typical chemical analyses.)

a. Alabama

Carbonate rocks occur widely in Alabama with bands generally crossing the state from west to east. High grade deposits of both limestone and dolomite exist.

A large formation extending west-east throughout the northern counties contains high purity limestone. In the central part of the state, a chalky limestone extends eastward from the Mississippi border in a wide and narrowing belt before disappearing in Russell County. It ranges in purity up to 85% calcium carbonate. Narrow beds of soft limestone occur in southern Alabama and are locally of high purity.

Bands of limestone and dolomite extend from the northeastern corner of the state southwesterly into the Birmingham area. High quality stones of both types are found. An exceptionally high grade dolomite, typically exceeding 98% in total carbonates, outcrops in the Birmingham area. A very pure marble, containing 98-99% calcium carbonate is also found in central Alabama. It occurs in a belt which extends northeast-southwest through Talladega and Coosa Counties. Shell occurs in Mobile Bay.

b. Kentucky

Vast quantities of limestone occur in Kentucky, with deposits throughout the state. In western Kentucky, a wide semi-circular outcrops curves from Livingston and Crittenden Counties through the southern border area to Warren County, where it swings north to Meade County. High-calcium limestones occur, particularly in the west and east branches of the deposit. Another outcrop, which is locally high grade limestone, is found in the Lexington area. A thinning belt of limestone extends northeastward from Cumberland County in the north. In many places it contains high-calcium

TABLE 10

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS

EAST SOUTH CENTRAL REGION

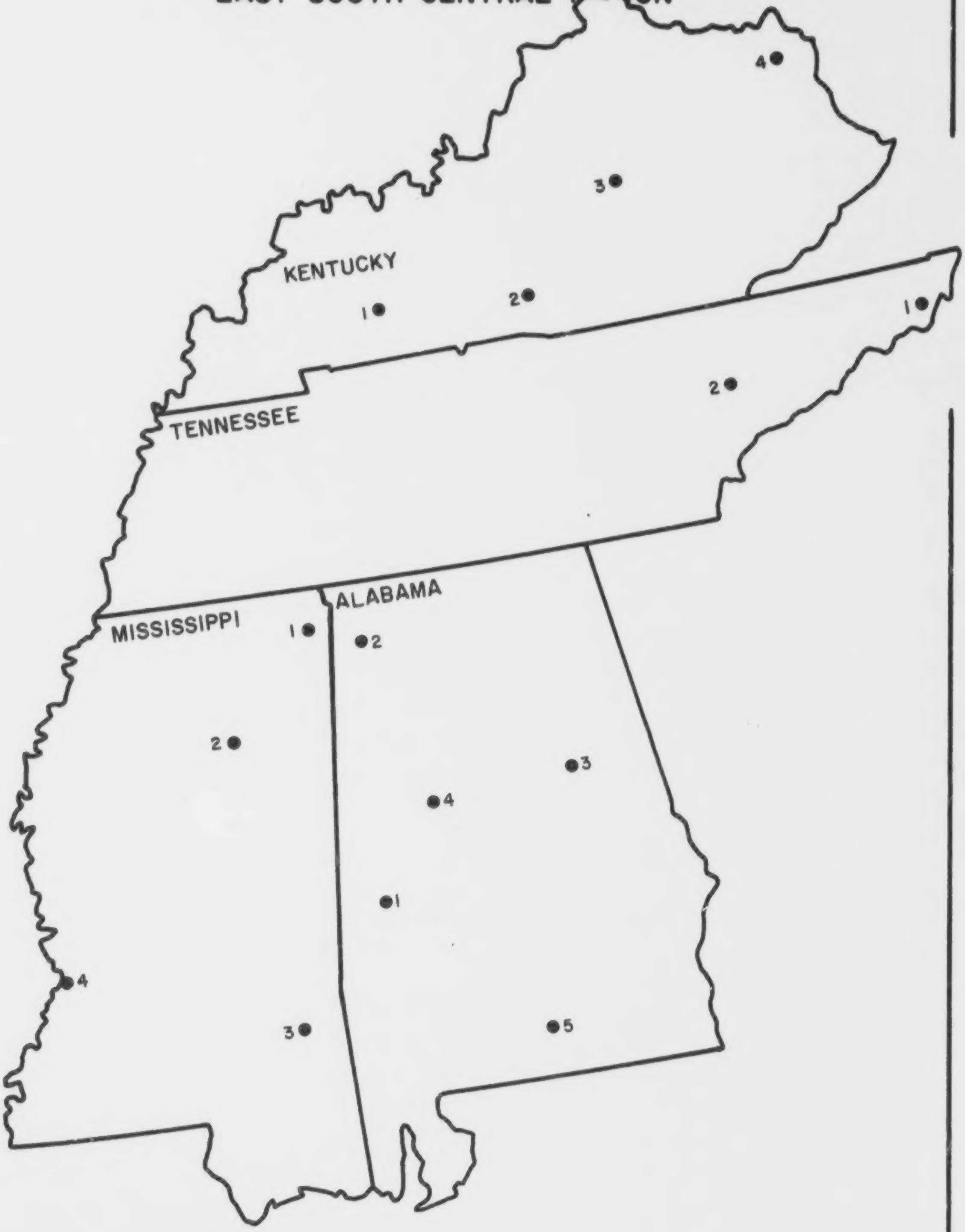
State	Sample No.[1]	Chemical Composition (weight %)					
		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
Alabama							
	1	78.57	1.38	15.18	←←←←2.22→→→→→		2.10
	2	96.58	2.58	0.50	←←←←1.45→→→→→		
	3	99.19	0.14	0.28	←←←←0.28→→→→→		
	4	88.85	3.52	4.48	←←←←1.22→→→→→		
	5	98.51	0.21	0.83	0.16	0.12	
Kentucky							
	1	82.88	4.20	4.26	←←←←4.33→→→→→		1.38
	2	98.05	0.36	1.06	←←←←0.51→→→→→		0.54
	3	90.72	4.61	1.88	←←←←2.70→→→→→		0.35
	4	95.15	0.24	3.06	←←←←1.39→→→→→		
Mississippi							
	1	94.15	0.75	1.57	1.94	1.69	0.13
	2	81.24	0.75	8.80	2.86	4.08	0.15
	3	86.46		6.30	←←←←7.20→→→→→		
	4	77.76	2.70	13.41	1.74	2.63	0.32
Tennessee							
	1	79.59	10.55	1.14	←←←←8.67→→→→→		
	2	98.85	TR		0.14	0.06	

(1) Sample numbers correspond to those shown on Figure 13.

FIGURE 13

SAMPLE LOCATIONS OF CARBONATE ROCKS

EAST SOUTH CENTRAL REGION


KENTUCKY
1
2
3
4
TENNESSEE
1
2
MISSISSIPPI
1
2
3
4
ALABAMA
1
2
3
4
5

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 10)

stone. A narrow limestone band occurs in the southeastern border counties.

c. Mississippi

There are two large occurences of limestone in Mississippi. A wide, thick chalk deposit extends north to south through northeastern counties. It is a soft, argillaceous limestone generally containing less than 85% calcium carbonate, although in certain areas the purity may exceed 90%. A second outcrop of limestone occurs in an east to west band through central Mississippi.

d. Tennessee

Extensive deposits of carbonate rocks occur in Tennessee, all within the eastern and central parts. In a broad area running northeast-southwest through eastern Tennessee, limestones and dolomites which are locally high grade can be found. Another large area in the central part of the state contains limestone which frequently outcrops as high calcium stone, particularly in the southern region. An exceptionally pure high calcium marble also occurs in eastern Tennessee, chiefly in the Knox County region.

7. West South Central

(See Table 11 and Figure 14 for typical chemical analyses.)

a. Arkansas

Limestone occurs in northern Arkansas in a belt which extends from White County westward to the Oklahoma line. It is a thick deposit which contains a few outcrops of marble and high grade dolomite in addition to high calcium limestone. The marble is an almost pure calcium carbonate and generally occurs in thin beds.

In southwest Arkansas, chalk deposits exist in thick beds. It is relatively impure, grading into marl.

b. Louisiana

Limestone occurs in central Louisiana in Winn and Evangeline Counties. The deposit in Winn County is a high calcium stone. Shell is found throughout the coastal region.

c. Oklahoma

Large deposits of carbonate rocks are found in Oklahoma, chiefly in the eastern and southern regions. Limestone outcrops in a wide band covering the northeastern corner of the state, reaching south to Sequoyah County. Deposits of high calcium stone occur in the southern portions of this band. Other belts of limestone occur widely throughout the northeastern counties. The flat lying beds are frequently shaly, although some high grade limestone does exist.

Generally thin bands of stone occur in south central and southeastern Oklahoma, but one large deposit outcrops extensively in Pontotoc, Carter, and Johnston Counties. Both high calcium

TABLE 11

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS

WEST SOUTH CENTRAL REGION

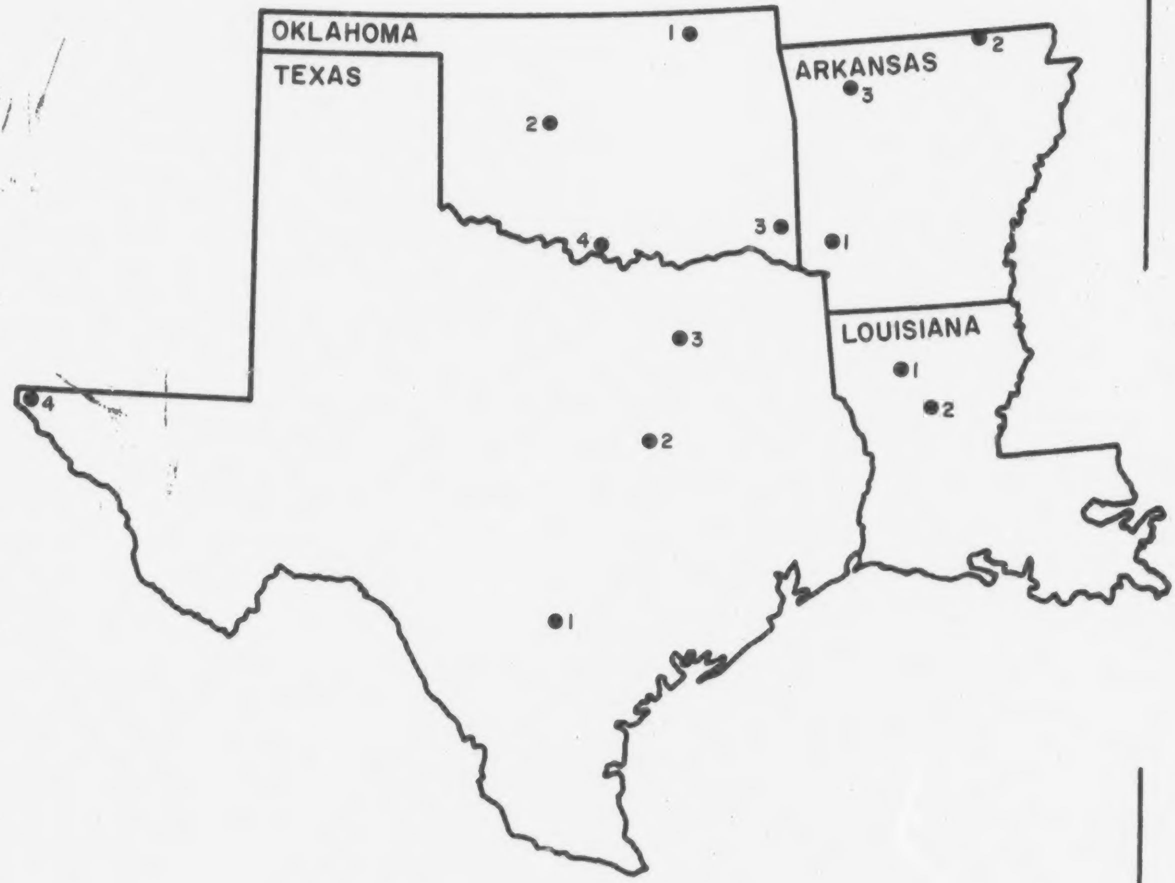
State	Sample No.(1)	Chemical Composition (weight %)					
		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
Arkansas							
	1	80.38	0.92	14.68	←2.15→		
	2	98.71	0.73	0.09	←0.11→		0.90
	3	98.34		0.50			
Louisiana							
	1	96.55	0.13	0.55	1.61		0.02
	2	98.19	1.26	0.65	TR	TR	0.11
Oklahoma							
	1	93.71	1.07	2.96	0.63	1.11	
	2	57.05	42.01	0.88		0.05	
	3	97.82	1.26	1.3	1.0		
	4	96.43	0.29	2.58	0.56	0.54	
Texas							
	1	81.7	1.3	11.9	4.2	0.5	
	2	85.8	0.6	8.0	2.8	1.15	
	3	90.0	0.8	4.2	1.4	1.72	
	4	93.47	2.11	3.22	0.78	0.28	0.37

(1) Sample numbers correspond to those shown on Figure 14.

FIGURE 14

SAMPLE LOCATIONS OF CARBONATE ROCKS

WEST SOUTH CENTRAL REGION


OKLAHOMA
TEXAS
ARKANSAS
LOUISIANA
1
2
3
4
1
2
3
4
1
2
3
1
2

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE II) limestone and high grade dolomite are found. Thin, steeply dipping beds of stone are found scattered throughout the southwestern counties. Most of this is dolomitic.

d. Texas

Limestones outcrop in an enormous band extending from the north central and northeastern border through central Texas to the southwestern area. The eastern edge of this band consists of a large, thick formation of soft chalk which reaches from the northeastern border to the San Antonio region. Locally it may be high purity limestone, but most commonly it ranges from 70% to 90% calcium carbonate. Paralleling this formation to the west are other large groups of limestones which outcrop in thick beds. They are frequently magnesian, but occurrences of high calcium limestone are found. A high grade dolomite occurs in the Burnet County region. In El Paso County in extreme western Texas, deposits of good quality limestone and dolomite exist.

Shell deposits occur in bay waters of the area between Corpus Christi and Galveston. Marble outcrops occasionally in central Texas.

8. Mountain

(See Table 12 and Figure 15 for typical chemical analyses.)

a. Arizona

The principal limestone deposits in Arizona occur in two regions. Thick deposits containing large quantities of high calcium stone are scattered throughout the southeastern part of the state. A more or less continuous but irregular band extends from east central Arizona to the northwest corner and contains thick beds of high calcium stone. Scattered outcrops of marble are exposed in various places, chiefly in the southeast. Magnesian limestones and dolomites also occur in Arizona but are frequently interbedded with chert, gypsum, sand or silt.

b. Colorado

Colorado has abundant reserves of carbonate rocks. A band of limestone extends from north central Colorado southward to Douglas County. In places it approaches high calcium limestone, but most of the formation is shaly. To the west of this band are scattered outcrops of limestone which locally contain high calcium stone. The most important high purity limestones occur in central Colorado. Outcrops of high grade dolomite and marble are also found here.

c. Idaho

Idaho's reserves of carbonate rocks are abundantly distributed throughout the state, with the northwest, central and southeastern regions being the most important. In the northwest, the rock varies from limestone to dolomite to marble, with high calcium limestone and high purity dolomite available. High calcium stone also appears along the western border and includes some rock which exceeds 98% in calcium carbonate content. Central and southeastern Idaho contains large deposits of limestone. Numerous outcrops of high quality stone occur. A siliceous, magnesian limestone also is found in the southeastern region.

TABLE 12

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS

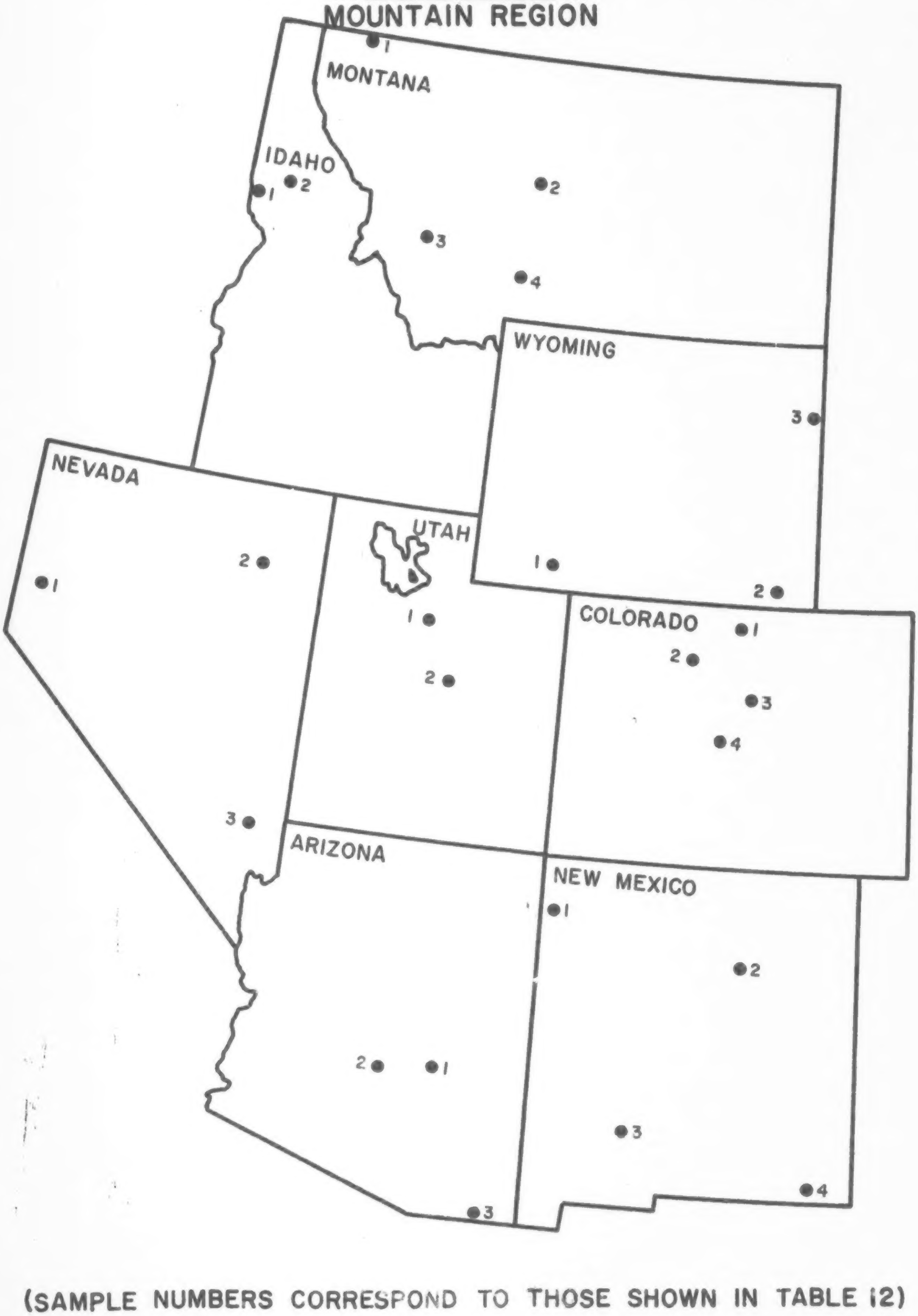
MOUNTAIN REGION

		Chemical Composition (weight %)					
State	Sample No.(1)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
Arizona							
	1	95.77	1.26	3.30	←←←←0.20→→→→		
	2	96.66		1.4	←←←←1.3 →→→→		
	3	48.69	36.42	12.53	1.04	1.26	
Colorado							
	1	90.48	1.17	5.33	1.54	0.71	0.33
	2	90.28	0.75	6.54	←←←←0.92→→→→		
	3	86.97	6.17	5.32	←←←←0.91→→→→		
	4	99.07	0.36	0.51	←←←←0.10→→→→		
Idaho							
	1	99.10	0.36	0.48	0.48	TR	0.28
	2	92.75	6.17	0.37	←←←←0.12→→→→		
Montana							
	1	98.62	1.59		0.05		
	2	53.07	41.36	4.98	0.96	0.50	0.05
	3	79.07	1.88	17.7		0.4	0.08
	4	95.99	0.46	2.85	0.19	0.29	
Nevada							
	1	98,45	1.59	0.04	0.05		
	2	97.30	0.56	1.25	←←←←0.36→→→→		
	3	86.61	5.15	7.38	0.80	0.68	
New Mexico							
	1	81.82	1.52	13.04	1.08		
	2	97.99	0.91	0.71	←←←←0.61→→→→		
	3	97.10	1.59	0.73	0.23	0.16	
	4	65.60	34.00	0.14	0.06	0.07	
Utah							
	1	94.51	1.82	2.77			
	2	95.90	1.88	2.0	0.7	0.1	
Wyoming							
	1	60.38	1.55	23.47	6.27	2.20	0.38
	2	80.33	5.54	6.44	1.46	2.32	0.69
	3	94.33	1.51	1.42	0.68	0.40	1.11

(1) Sample numbers correspond to those shown on Figure 15.

FIGURE 15

SAMPLE LOCATIONS OF CARBONATE ROCKS ... ... MOUNTAIN REGION


MONTANA
1
2
3
4
IDAHO
1
2
WYOMING
1
2
3
NEVADA
1
2
3
UTAH
1
2
COLORADO
1
2
3
4
ARIZONA
1
2
3
NEW MEXICO
1
2
3
4

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 12)

d. Montana

The most important deposits of carbonate rocks occur in central and western Montana. One large formation outcrops as thick beds in many places in the western region and contains several beds of exceptionally high calcium limestone (>98-99%). Another formation, which is commonly dolomitic, occurs in the central and western counties and has exposures of high quality stone of both types. A thin-bedded limestone which is frequently interbedded with chert and shale is also found. Nearly pure marbles ranging in composition from calcitic to dolomitic outcrops as thick beds in the southwest.

e. Nevada

Nevada has large reserves of carbonate rocks occurring principally in the eastern third of the state. Limestone and dolomite are found in a band of discontinuous deposits which extend northward from the southeastern tip of the state to the northeast corner. High grade dolomite and a very high purity limestone outcrop in Clark County. High calcium limestone also is exposed in several places in White Pine County, and probably occurs in several other places throughout the belt. Although western Nevada has fewer and more impure deposits of limestone, a high calcium limestone is known to exist in southern Washoe County. Mineral County, in the southwest, has occurrences of marble.

f. New Mexico

Abundant reserves of limestone and dolomite occur in New Mexico in numerous deposits throughout the state. The most important outcrops, however, are found in central to south central New Mexico, with the southwestern region also having significant deposits. These areas contain most of the high calcium limestone and high grade dolomite in the state in frequently large, thick beds. Other regions have large quantities of limestone, but the deposits are usually impure with only locally high grade stone available. Of note is an extensive area of impure limestone which covers most of the far eastern counties from the Texas to Colorado borders.

g. Utah

Extensive deposits of limestone and dolomite are found in Utah, chiefly in the north central region. High quality stone of both types outcrops in numerous places in the region. A silty, argillaceous limestone is also exposed. In limited amounts, veins of crystalline, nearly pure calcium carbonate occur not only as common calcite but also in the rare form of aragonite.

Important deposits are also located in western Utah and contain high calcium limestone and high purity dolomite.

h. Wyoming

Limestone occurs abundantly in Wyoming in deposits scattered throughout all areas of the state. Outcrops of high calcium limestone are numerous. Notably important deposits of high calcium stone are found in the southeastern part of the state and in Teton County in the northwest. A narrow band of impure chalk or soft, shaly limestone occurs in thick beds in the northeastern region. Marble deposits exist in several places in Platte County.

9. Pacific

(See Table 13 and Figure 16 for typical chemical analyses.)

a. California

California has large reserves of carbonate rocks, but the deposits are scattered throughout the state in the form of discontinuous, irregular, steeply dipping bodies of small areal extent. Commonly they are interbedded with various impurities and have variable magnesium contents. Limestone and dolomite are restricted largely to inland regions with little in coastal areas. However, substantial deposits occur in the coastal region around San Francisco and contain good quality high calcium limestone. Locally high grade limestone and dolomite also are found in many other parts of the state. Shell deposits exist along the coast, chiefly in San Francisco Bay.

b. Oregon

The most significant deposits of limestone occur in the southwest and northeast regions of Oregon. The southwest area has reserves of high grade limestone occurring in a series of small lenses, chiefly in Josephine County. Larger deposits of limestone occur in the northeastern region and contain significant quantities of high calcium stone. A few lenses of impure, siliceous limestone occur in the northwest.

c. Washington

Carbonate rock deposits occur chiefly in the northwestern and northeastern Washington area, notably in San Jaun and Stevens Counties. The northwestern region contains a large amount of crystalline, high calcium limestone. Both high grade dolomite and high calcium limestone occur in the northeast. Marble also is found in Stevens County.

ties of limestone, but the deposits are usually impure with only locally high grade stone available. Of note is an extensive area of impure limestone which covers most of the far eastern counties from the Texas to Colorado borders.

g. Utah

Extensive deposits of limestone and dolomite are found in Utah, chiefly in the north central region. High quality stone of both types outcrops in numerous places in the region. A silty, argillaceous limestone is also exposed. In limited amounts, veins of crystalline, nearly pure calcium carbonate occur not only as common calcite but also in the rare form of aragonite.

Important deposits are also located in western Utah and contain high calcium limestone and high purity dolomite.

h. Wyoming

Limestone occurs abundantly in Wyoming in deposits scattered throughout all areas of the state. Outcrops of high calcium limestone are numerous. Notably important deposits of high calcium stone are found in the southeastern part of the state and in Teton County in the northwest. A narrow band of impure chalk or soft, shaly limestone occurs in thick beds in the northeastern region. Marble deposits exist in several places in Platte County.

9. Pacific
(See Table 13 and Figure 16 for typical chemical analyses.)

a. California

California has large reserves of carbonate rocks, but the deposits are scattered throughout the state in the form of discontinuous, irregular, steeply dipping bodies of small areal extent. Commonly they are interbedded with various impurities and have variable magnesium contents. Limestone and dolomite are restricted largely to inland regions with little in coastal areas. However, substantial deposits occur in the coastal region around San Francisco and contain good quality high calcium limestone. Locally high grade limestone and dolomite also are found in many other parts of the state. Shell deposits exist along the coast, chiefly in San Francisco Bay.

b. Oregon

The most significant deposits of limestone occur in the southwest and northeast regions of Oregon. The southwest area has reserves of high grade limestone occurring in a series of small lenses, chiefly in Josephine County. Larger deposits of limestone occur in the northeastern region and contain significant quantities of high calcium stone. A few lenses of impure, siliceous limestone occur in the northwest.

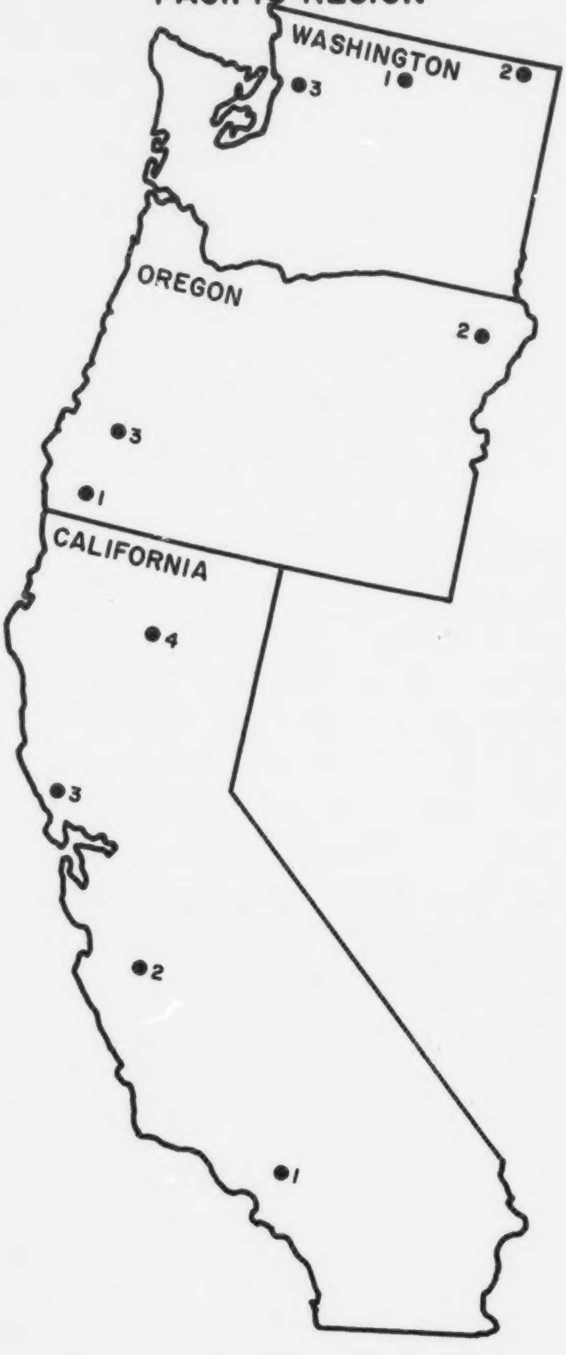
c. Washington

Carbonate rock deposits occur chiefly in the northwestern and northeastern Washington area, notably in San Jaun and Stevens Counties. The northwestern region contains a large amount of crystalline, high calcium limestone. Both high grade dolomite and high calcium limestone occur in the northeast. Marble also is found in Stevens County.

FIGURE 16

SAMPLE LOCATIONS OF CARBONATE ROCKS

PACIFIC REGION


WASHINGTON
3
1
2
OREGON
2
3
1
CALIFORNIA
4
3
2
1

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 13)

TABLE 13

TYPICAL CHEMICAL COMPOSITION OF CARBONATE ROCKS

PACIFIC REGION

State	Sample No.(1)	Chemical Composition (weight %)					
		$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	Other
California							
	1	72.68	1.05	19.72	←←←3.27→→→		2.43
	2	99.2		0.7			
	3	95.20	1.32	1.27	←←←0.23→→→		1.78
	4	91.04	1.05	4.00	←←←1.50→→→		
Oregon							
	1	96.68	0.84	1.73	1.69	0.30	
	2	97.28	1.09	0.92	0.34	TR	
	3	96.10	0.69	2.67	0.55	0.70	
Washington							
	1	94.3	2.1	1.3	TR	0.12	
	2	95.5	1.1	2.3	0.4	0.23	
	3	98.1	TR	0.2	←←←1.4→→→→		

(1) Sample numbers correspond to those shown on Figure 16.

VIII. PRODUCTION, USE AND VALUE OF CARBONATE STONES

A. The Limestone Industry

Stone was the fourth leading mineral commodity produced in the United States in 1969, ranking behind crude petroleum, natural gas, and coal in total value. Over 1.4 billion dollars worth of stone were quarried, representing 5.3% of the total value of all minerals produced in the nation. Production of all stone amounted to 863 million tons.

The stone industry can be divided into two branches, dimension stone and crushed stone, but other than the basic raw materials, there is little in common between the two. Methods of quarrying, processing, and marketing, in addition to uses and values, are fundamentally different.

Dimension stone can be defined as naturally occurring rock which is cut or otherwise fashioned into blocks, slabs, sheets, or other units of specified sizes and shapes. It is used principally as architechtural and building stone, monumental stone, curbing, flagging, and paving stone. Production was reported from all but a few states, with Indiana (limestone), Georgia (granite), and Ohio (sandstone) being the leading producers. In 1969, the total output was about 1.9 million tons, valued at 99 million dollars. This represented only 0.2% of the total stone tonnage, but 6.9% of its total value. The national average value exceeded $50/ton. Limestone, dolomite, and marble were all quarried as dimension stone and accounted for roughly one-third of all dimension stone reported in 1969.

Crushed stone can be defined as irregularly shaped rock fragments which are broken into smaller sizes after quarrying. It accounted for the overwhelming majority of stone produced in the United States in 1969. Production came from over 4700 quarries located throughout all of the states in the country. A variety of rocks were quarried including calcareous marl, granite, limestone, dolomite, marble, sandstone, quartz, quartzite, shell, traprock, and others.

The primary use of crushed rock in the United States is for construction purposes, particularly as an aggregate material in road construction. These markets consumed almost 620 million tons, or about 72% of the total crushed stone produced in the United States. For these uses, the physical properties of the stone are important. Such characteristics as strength, toughness, abrasion resistance, inertness, proper shape, size, and size distribution determine whether or not the material is suitable for a particular construction application. Chemical composition is unimportant.

In relation to total crushed stone, limestone and related materials accounted for about three-fourths of the total production in 1969. Output of carbonate stones (used here to include limestone, dolomite, shell, marble, and calcareous marl) amounted to almost 653 million tons. Production of limestone far exceeded that of any other type of stone.

Since the bulk of the crushed stone production is used in construction, and since carbonate stones account for a very large part of the total crushed stone, construction applications comprise a major market for these carbonate stones. For these markets, physical characteristics are of paramount importance, and the chemical composition has no bearing on the stone's utility. Hence, the carbonate rocks must compete against all of the other types of rocks previously enumerated. In addition, sand, gravel, blast furnace slag, and lightweight aggregate, which are also used as construction materials, afford further competition.

A carbonate stone is an essential raw material for many other important industrial uses (cement, lime, glass, etc.), which consume large tonnages each year. In these instances, the rocks are valued for their chemical characteristics and, therefore, do not compete against the other rock types. Here too, though, competition frequently exists between the various types of carbonate stones. For example, both limestone and shell have been used as a source of high-purity calcium carbonate for use in the manufacture of lime.

From the previous considerations, it is apparent that many similarities exist between the limestone (or carbonate stone) industry and the crushed stone industry as a whole. Problems, production methods, and marketing techniques are, for the most part, closely linked between the two. Even that branch of the limestone industry which produces 'chemical' limestone has many aspects in common with the crushed stone industry.

1. Definition of Uses

Subsequent sections include a discussion of the more important uses of limestone and related materials as reported in the various states. A brief explanation of these uses follows:

Bituminous Aggregate - sized stone, of gradations from 2 inches to 8 mesh, used with asphalt or tar in the construction of roads.

Concrete Aggregate - sized stone, of gradations from 3-1/2 inches to 4 mesh, used with cement to form a concrete construction material for a wide variety of applications.

Dense Graded Road Base Stone - sized stone, of gradations from 3-1/2 inches to 0(1), used as a base course in road construction.

---

(1) This designation indicates stone with a maximum size of 3-1/2" and no minimum size.

Macadam Aggregate - sized stone, of various gradations from about 3 inches to 0[1], used in the construction of macadam roads.

Manufactured Fine Aggregate (Stone Sand) - stone crushed

to the size of sand grains and used in place of silica sand for numerous construction purposes.

Surface Treatment Aggregate - sized stone, of gradations from 1 inch to 16 mesh, used frequently with asphalt to improve or cover worn-out surfaces.

Agricultural Applications - Limestone and dolomite serve several important functions as agricultural materials. They are used to correct soil acidity, replenish elements, improve physical or biological conditions in the soil, increase the efficiency of fertilizers, and for other purposes. A high-calcium limestone or high-purity dolomite is desirable, but not essential. The stone is generally 8 to 100 mesh.

Cement Manufacture - Limestone is the prime ingredient in the manufacture of cement. Although a high-purity stone is not required, dolomites and magnesian limestones can not be used. Argillaceous limestone, for example, find great applicability in cement manufacture.

Chemical Stone for Alkali Works - Limestone is an important raw material in the manufacture of sodium carbonate (soda ash) by the ammonia or Solvay process. A high-calcium limestone, generally of high purity, is used. A size of 1 - 6 inches is preferred.

Dead-burned Dolomite - Dolomites or magnesian limestones are sintered and calcined at high temperatures to produce dead-burned dolomite, actually calcium and magnesium oxides. The material is used for refractory linings in open-hearth steel furnaces.

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(1) This designation indicates stone with a maximum size of 3" and no minimum size.

Ferrosilicon - Dolomite is calcined, and the lime produced is used as a raw material for the production of elemental magnesium by the ferrosilicon process.

Fill - Limestone and dolomite are sometimes used for landfill of swamps and land grading. For this purpose, type and purity of stone is unimportant.

Filter Stone - Limestone and dolomite are used as filter stone in the treatment of sewage. It provides an anchorage in which bacteria can lodge. Chemical composition is unimportant, though certain impurities should be avoided, but the stone must be strong, compact, fine-grained, and closely sized (about 1-1/2 - 3 inches).

Flux - Large quantities of stone are used in iron, steel, and other metallurgical furances to remove the acid impurities, chiefly silica and alumina, from ore. Both limestone and dolomite find application. The stone must be of high-purity (95%), strong, and relatively large-sized (generally 1/2 - 8 inches).

Glass - Both limestone and dolomite are used as basic raw materials in the manufacture of glass. Specifications on purity vary, but total carbonates are generally 90% or greater and, for optical glass, should be at least 99%. Usually, low iron, sulfur, and phosphorus contents are required.

Lime Manufacture - Lime is produced by the calcination of limestone or dolomite to drive off carbon dioxide. Physical and chemical requirements are rigid. Depending on the type of kiln employed, various stone gradations are used. For vertical kilns, the stone should be a minimum of 2 inches. Rotary kilns can calcine stone as small as 1/4 inch. Chemical purity generally exceeds 97% in total carbonates.

Mineral Filler - Limestone and dolomite are used as fillers or extenders for a wide variety of products including paints, puttys, paper, rubber, asphalt, and tiles. It is usually a high-purity stone which is finely divided.

Paper Manufacture - An acid liquor, prepared by reacting limestone with sulfur dioxide, is used to digest wood chips in the manufacture of paper. A high-purity, high-calcium stone of large size (up to 14 inches) is preferred.

Poultry Grit - Granular limestone of uniform sizes is used to allow poultry to grind its food. Chemical purity is unimportant. Almost any type of stone can be used.

Railroad Ballast - sized stone, of gradations from 2-1/2 inches to 4 mesh, used for the construction and maintenance of railway beds.

Refractory - In addition to dead-burned dolomite, raw stone may be used for refractory linings in metallurgical furnaces or as a patching material.

Riprap and Jetty Stone - large, irregular rocks used primarily for river and harbor work, shore protection, and spillways.

Roofing Granules - stone chips which are used as gravel with tar for coating roofs.

Sugar Refining - lime produced from a pure high-calcium limestone is used to remove impurities in the manufacture of sugar. However, the lime is usually produced from raw stone at the refinery.

Terrazzo and Exposed Aggregate - stone chips of about 1/2 - 3/4 inch wide. Coloring of the stone is an important consideration for this application.

Whiting - a pulverized limestone or dolomite. Many applications demand a white, highly pure, very fine (-325 mesh) stone having other rigid specifications.

2. Quarrying and Processing of Carbonate Stone

Carbonate stones are produced by a number of different methods including quarrying , mining, and dredging. Shell, of course, is recovered by dredging off the bottom in shallow waters. Under special economic circumstances underground mining is pursued but the most common method of stone recovery, by far, is quarrying.

There are two basic types of quarries -- open-shelf and open-pit. They differ chiefly in topographical features. Where stone is imbedded in a hillside above the level of the surrounding terrain, an open-shelf quarry is used to extract the stone by digging into the side of the hill. Open-pit quarries are the more common of the two types and are used where the stone lies below the natural level of the terrain. They may be quite shallow (10 - 20 feet), or the quarry floor may lie well below (200 feet or more) the grade of the surrounding land.

There is a great variety in operations, sequence, and equipment employed at different quarries. Factors such as stone characteristics, topography, condition of rock strata, type and thickness of overburden, height of quarry face, type and extent of markets, labor conditions, location of roads and rail facilities, and availability of electric power must all be considered to ensure the most desirable and profitable design. However, certain basic similarities exist. A typical quarry may be described as having the following operations:

1) removal of overburden
2) drilling
3) blasting
4) secondary breakage
5) hauling
6) crushing
7) conveying
8) sizing

9) washing
10) storage
11) reclamation
12) blending

The reader is referred elsewhere(1) for an excellent description of these operations in detail.

In 1969, a total of 4,711 crushed stone quarries was reported by the Bureau of Mines(2). No breakdown by type of stone was available. Of the total, over 37% had an annual production of less than 25,000 tons. However, these quarries accounted for only 1.8% of the nationwide production. Quarries which produced over 900,000 tons numbered 172, only 3.7% of the total number of quarries, but produced 33% of the total tonnage. The 364 largest quarries accounted for almost 50% of the total production. From these data, it is obvious that, although small quarries predominate in number, the major stone production comes from the larger operations.

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(1) Boynton, Robert S., Chemistry and Technology of Lime and Limestone, John Wiley & Sons, New York, 1966

(2) Mineral Industry Surveys, Stone in 1969, U.S. Bureau of Mines, Washington, D.C., August 28, 1970.

B. National Data

In this section, data are presented on production, uses, and unit values of various crushed and broken carbonate materials in the United States in 1969. In subsequent sections, these data are broken down into regional and state summaries. Much of this information has been derived either from data furnished by the United States Bureau of Mines or from one of their publications.(1)

Production figures and values are, in some cases, not directly reported by the Bureau of Mines. This is done to avoid disclosure of individual company confidential data. In these instances, the figures are reported indirectly, by combination with, or inclusion in, other categories. Generally this occurs where production is limited and, consequently has virtually no effect on the validity of the statistics as presented in this report.

Cost data are presented as unit values, in dollars per ton of crushed stone ($/ton). This is defined basically as the net selling value, or selling price, per ton of stone, f.o.b. quarry.

1. Production

Tables 14 and 15 show 1969 production data for various crushed and broken carbonate materials in the United States, including limestone, dolomite, shell, calcarcous marl, and marble. Materials such as chalk, coral, etc. are not shown specifically, since they are not listed as separate commodities by the Bureau of Mines.

The total national production of crushed carbonate rocks, as shown in Table 14, amounted to almost two-thirds of a billion tons in 1969, of which over 85% was limestone. Dolomite ranked second with over 10%. Marl and marble production were very low,

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(1) Mineral Industry Surveys, Stone in 1969, U.S. Bureau of Mines, Washington, D.C., August 28, 1970.

TABLE 14

PRODUCTION OF CRUSHED AND BROKEN CARBONATE STONES IN THE UNITED STATES IN 1969, BY TYPE

Type	Production (M Tons)
Limestone	558,793
Dolomite	68,380
Shell	19,731
Calcareous Marl	2,490
Marble	2,271
Total, All Types	651,665

TABLE 15

PRODUCTION OF CRUSHED AND BROKEN CARBONATE STONES IN THE UNITED STATES IN 1969, BY USE

Use	Production (M Tons)(1)
Agricultural Purposes	35,152
Concrete Aggregate (Coarse)	96,590
Bituminous Aggregate	46,429
Macadam Aggregates	23,422
Dense Graded Road Base Stone	147,596
Surface Treatment Aggregates	38,811
Unspecified Construction Aggregate and Roadstone	54,434
Ripcap and Jetty Stone	11,639
Railroad Ballast	6,173
Filter Stone	686
Manufactured Fine Aggregate (Stone Sand)	2,815
Terrazzo and Exposed Aggregate	164
Cement Manufacture	105,147
Lime Manufacture	31,714
Dead-Burned Dolomite	2,935
Ferrosilicon	148
Flux	30,360
Refractory	419
Chemical Stone for Alkali Works	3,273
Fill	2,739
Glass	992
Undistributed	11,218
Total, All Uses	652,856(2)

---

(1) Includes limestone, dolomite, shell, marl, and marble

(2) Includes 1,189 M tons of crushed limestone produced in Alaska and Hawaii; separate data for contiguous U.S. were not available

amounting to less than 5 million tons combined, or 0.7% of the total.

Table 16 shows, qualitatively, the various types of carbonate rocks produced in each state. Limestone was produced in all but 4 states, viz, Delaware, Louisiana, New Hampshire, and North Dakota. Louisiana, however, was the leading producer of shell in the United States. The other three states reported no carbonate rock production of any kind. Dolomite production was reported in 24 states covering all regions of the country, but was centered primarily in the states surrounding the Great Lakes. Shell was produced in 8 states, mainly along the Gulf Coast. The limited production of marl and marble, in 8 and 18 states respectively, occurred in various states throughout the country. Alabama was the leading producer of marble.

Table 15 lists the 1969 production of crushed carbonate rocks by use. Reflecting the large use of limestone and related materials for their physical rather than chemical properties was the huge consumption of carbonate rocks for various construction purposes. The total production for construction uses amounted to nearly 428 million tons, or almost two-thirds of the entire national production. Dense graded road base stone constituted the largest single use, amounting to almost 148 million tons, or 22.6% of the total national production. On the other hand, those uses for which a high-purity limestone or dolomite is required, or desirable, accounted for 70 million tons, or slightly more than 10% of the national total.

Marl finds its major use in cement manufacture since the normal silica and alumina impurities are desirable components which, combined with its softness, make it an ideal raw material. Most of the shell produced in the United States was used for construction purposes, with significant tonnages also being consumed in cement and lime manufacture. Marble was used chiefly for decorative purposes and other specialty markets.

TYPES OF CRUSHED AND BROKEN CARBONATE STONES PRODUCED IN THE UNITED STATES IN 1969, BY STATE

	Type of Carbonate Stone				
State	Limestone	Dolomite	Shell	Calcareous Marl	Marble
Alabama	x	x	x		x
Arizona	x				x
Arkansas	x				
California	x	x	x		x
Colorado	x	x			x
Connecticut	x	x			
Delaware	--------------	--------------	No Production	--------------	--------------
Florida	x		x		
Georgia	x				x
Idaho	x				
Illinois	x	x			
Indiana	x	x		x	
Iowa	x	x			
Kansas	x				
Kentucky	x				
Louisiana			x		
Maine	x				
Maryland	x		x		x
Massachusetts	x	x			
Michigan	x	x		x	
Minnesota	x	x		x	
Mississippi	x			x	
Missouri	x	x			x
Montana	x				x
Nebraska	x				
Nevada	x	x		x	x
New Hampshire	--------------	--------------	No Production	--------------	--------------
New Jersey	x				x
New Mexico	x				
New York	x	x			x
North Carolina	x				x
North Dakota	--------------	--------------	No Production	--------------	--------------
Ohio	x	x			
Oklahoma	x	x			
Oregon	x				
Pennsylvania	x	x	x		
Rhode Island	x				
South Carolina	x			x	
South Dakota	x				
Tennessee	x				x
Texas	x	x	x	x	x
Utah	x	x			
Vermont	x	x			x
Virginia	x	x	x	x	x
Washington	x	x			x
West Virginia	x	x			
Wisconsin	x	x			
Wyoming	x				x

2. Value

Table 17 shows the unit values of various carbonate materials in 1969. These are average values for the entire United States and range from a low of $1.01/ton for marl to a high of $9.69/ton for marble, with a national average of $1.49/ton for all carbonate rocks. The high unit value for marble reflects its specialty uses. The materials produced in the largest quantities (i.e., limestone, dolomite, and shell) all average between $1.42 - 1.55/ton.

The unit values for all carbonate materials are broken down by use in Table 18. They range from a low of $0.69/ton for stone used as fill to a high of $6.00/ton for stone used for terrazzo floors and as exposed aggregate. Uses which command a high price include filter stone, refractory stone, and stone for glass manufacture. Of the twenty-one uses shown, however, only four have average unit values exceeding $2.00/ton, and these account for only 2.3 million tons, or 0.3% of the total crushed carbonate rock production in 1969.

Stone used for construction purposes, amounting to 428 million tons (see Table 15), averaged $1.44/ton and fell within the small range of $1.29 - 1.69/ton. The 70 million tons of carbonate stone used for purposes where a high-purity limestone or dolomite is required (lime, dead-burned dolomite, ferrosilicon, flux, refractory, chemical stone, and glass) had an average unit value of only $1.69/ton. It is interesting to note that even though this latter stone is high-purity, the unit value for most uses is quite low. In only two cases (refractory, glass) did it exceed $2.00/ton.

C. Regional Data

In subsequent sections of this report, data on production, use, and value for crushed carbonate stones are presented by state and region. Table 19 shows limestone and dolomite

TABLE 17

UNIT VALUE OF CRUSHED AND BROKEN CARBONATE STONES IN THE UNITED STATES IN 1969, BY TYPE

Type	Unit Value ($/Ton)
Limestone)	(1.45(1)
Dolomite)	1.46 (1.55(1)
Shell	1.42
Calcareous Marl	1.01
Marble	9.69
Average, All Types	1.49

---

(1) The separate values for limestone and dolomite are estimates.

TABLE 18

UNIT VALUE OF CRUSHED AND BROKEN CARBONATE STONES IN THE UNITED STATES IN 1969, BY USE

Use	Unit Value ($/Ton)(1)
Agricultural Purposes	1.79
Concrete Aggregate (Coarse)	1.54
Bituminous Aggregate	1.51
Macadam Aggregates	1.48
Dense Graded Road Base Stone	1.33
Surface Treatment Aggregates	1.44
Unspecified Construction Aggregate and Roadstone	1.54
Ripcap and Jetty Stone	1.30
Railroad Ballast	1.29
Filter Stone	2.01
Manufactured Fine Aggregate (Stone Sand)	1.69
Terrazzo and Exposed Aggregate	6.00
Cement Manufacture	1.13
Lime Manufacture	1.82
Dead-Burned Dolomite	1.58
Ferrosilicon	1.36
Flux	1.50
Refractory	2.45
Chemical Stone for Alkali Works	1.72
Fill	0.69
Glass	3.16
Average, All Uses	1.49

---

(1) Includes limestone, dolomite, shell, marl, and marble.

TABLE 19

PRODUCTION OF CRUSHED AND BROKEN LIMESTONE AND DOLOMITE IN THE UNITED STATES IN 1969, BY REGION AND STATE

Region and State	Production (M Tons) Limestone	Dolomite	Total
New England			
Connecticut	I(1)	I	(275)(2)
Maine	(800)	-	(800)
Massachusetts	I	I	(750)
New Hampshire	-	-	-
Rnode Island	(<100)	-	(<100)
Vermont	I	I	(525)
Totals	I	I	(2,400)
Middle Atlantic			
New Jersey	(800)	-	(800)
New York	28,241	5,216	33,457
Pennsylvania	47,158	9,509	56,667
Totals	(76,200)	14,725	(90,900)
East North Central			
Illinois	40,172	14,672	54,844
Indiana	22,880	2,277	25,157
Michigan	30,659	8,407	39,066
Ohio	38,081	12,514	50,595
Wisconsin	14,209	1,728	15,937
Totals	146,001	39,598	185,599
West North Central			
Iowa	I	I	(26,200)
Kansas	15,334	-	15,334
Minnesota	3,289	838	4,127
Missouri	40,268	932	41,200
Nebraska	4,663	-	4,663
North Dakota	-	-	-
South Dakota	989	-	989
Totals	I	I	(92,500)

TABLE 19 (Cont'd)

PRODUCTION OF CRUSHED AND BROKEN LIMESTONE AND DOLOMITE IN THE UNITED STATES IN 1969, BY REGION AND STATE

Region and State	Production (M Tons)		
	Limestone	Dolomite	Total
South Atlantic			
Delaware	-	-	-
Florida	40,729	-	40,729
Georgia	4,334	-	4,334
Maryland	9,804	-	9,804
North Carolina	(4,500)	-	(4,500)
South Carolina	(1,900)	-	(1,900)
Virginia	13,471	4,358	17,829
West Virginia	6,191	2,214	8,405
Totals	(80,900)	6,572	(87,500)
East South Central			
Alabama	15,614	2,138	17,752
Kentucky	30,158	-	30,158
Mississippi	(300)	-	(300)
Tennessee	33,109	-	33,109
Totals	(79,200)	2,138	(81,300)
West South Central			
Arkansas	5,676	-	5,676
Louisiana	-	-	-
Oklahoma	I	I	(16,300)
Texas	I	I	(36,300)
Totals	I	I	(58,300)
Mountain			
Arizona	2,339	-	2,339
Colorado	I	I	(1,650)
Idaho	(250)	-	(250)
Montana	1,442	-	1,442
Nevada	I	I	(1,000)
New Mexico	956	-	956
Utah	I	I	(2,400)
Wyoming	649	-	649
Totals	I	I	(10,700)

TABLE 19 (Cont'd)

PRODUCTION OF CRUSHED AND BROKEN LIMESTONE AND DOLOMITE IN THE UNITED STATES IN 1969, BY REGION AND STATE

Region and State	Production (M Tons) Limestone	Dolomite	Total
Pacific			
California	I	I	(17,400)
Oregon	(350)	-	(350)
Washington	749	(300)	(1,050)
Totals	I	I	(18,800)

---

(1) "I" indicates that insufficient data were available to estimate production.

(2) ( ) indicates that production figure was estimated.

production broken down in this manner. In many cases exact production figures were not available and for these, estimates were made wherever possible. These estimates are based on consideration of 1969 total stone production, 1969 production of various rocks other than carbonate, and production rates of all types of stone reported in previous years.(1)(2) From Table 19, the total limestone and dolomite produced in the United States in 1969, including estimated production rates, was 627,999,000 tons. This agrees very well with the actual figures of 627,173,000 tons reported by the Bureau of Mines.

Data on production of the other carbonate rocks are not tabulated by state due to the limited production of these materials and the meager amount of available data. However, where exact figures are known, or where estimates can be made, they are noted in the text.

Table 20 shows unit values for the carbonate rocks by state and region. These data are derived from information furnished by the Bureau of Mines. It should be noted here that the unit values shown for the various materials in each state do not necessarily correspond to the total production of these materials. Certain uses, e.g., those consuming stone requiring special processing and commanding premium prices, are excluded. This was done to avoid inflating the value for the type and quality of stone suitable for use in air pollution control.

No data are available for uses in 1969 by state. However, based on information on uses for previous years, a qualitative discussion of use pattern is given for each state.

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(1) 1967 Minerals Yearbook, Vol. I-III, U.S. Bureau of Mines, Washington, D.C., 1969.

(2) 1968 Materials Yearbook, Vol. I-III, U.S. Bureau of Mines, Washington, D.C., 1970.

TABLE 20

UNIT VALUE OF CRUSHED AND BROKEN CA
IN THE UNITED STATES IN 1969, BY RE

							Unit
	Limestone			Dolomite			
Region and State	Low	High	Avg.	Low	High	Avg.	Lo
New England							
Connecticut	NR(1)	NR	NR	3.30	5.87	4.20	-(
Maine	1.10	3.00	1.32	-	-	-	-
Massachusetts	1.75	5.02	4.14	5.24	5.24	5.24	-
New Hampshire	-	-	-	-	-	-	-
Rhode Island	5.90	9.50	7.57	-	-	-	-
Vermont	0.76	16.75	1.46	1.48	2.76	1.53	-
Middle Atlantic							
New Jersey	1.50	14.89	2.49	-	-	-	-
New York	0.64	3.54	1.56	1.25	5.00	1.97	-
Pennsylvania	0.50	4.19	1.46	0.61	3.50	1.73	NR
East North Central							
Illinois	0.37	6.25	1.44	1.10	2.50	1.45	-
Indiana	0.78	4.48	1.32	0.65	1.61	1.28	-
Michigan	0.72	2.96	1.02	0.57	26.00	1.45	-
Ohio	0.50	4.59	1.54	0.34	3.28	1.48	-
Wisconsin	0.14	3.50	1.17	0.77	2.00	1.21	-
West North Central							
Iowa	0.43	2.67	1.49	1.21	2.20	1.72	-
Kansas	0.20	5.00	1.40	-	-	-	-
Minnesota	0.75	15.00	1.32	0.64	1.70	1.38	-
Missouri	0.74	7.65	1.39	0.85	1.50	1.13	-
Nebraska	1.24	2.70	1.87	-	-	-	-
North Dakota	-	-	-	-	-	-	-
South Dakota	0.73	2.00	1.22	-	-	-	-
South Atlantic							
Delaware	-	-	-	-	-	-	-
Florida	0.50	3.33	1.31	-	-	-	1.0
Georgia	0.82	2.20	1.50	-	-	-	-
Maryland	0.59	9.59	1.57	-	-	-	NR
North Carolina	1.35	2.35	1.62	-	-	-	-
South Carolina	0.35	1.79	1.51	-	-	-	-
Virginia	0.70	4.57	1.52	1.00	1.91	1.37	3.
West Virginia	0.34	24.00	1.62	1.00	2.15	1.62	-

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(1) "NR" indicates that value was not reported.
(2) "-" indicates no production.

TABLE 20

CRUSHED AND BROKEN CARBONATE STONES
STATES IN 1969, BY REGION AND STATE

Unit Value ($/Ton)										
olomite		Shell			Calcareous Marl			Marble		
High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.
5.87	4.20	-(2)	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
5.24	5.24	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
2.76	1.53	-	-	-	-	-	-	1.41	1.41	1.41
-	-	-	-	-	-	-	-	25.00	25.00	25.00
5.00	1.97	-	-	-	-	-	-	3.00	3.00	3.00
3.50	1.73	NR	NR	NR	-	-	-	-	-	-
2.50	1.45	-	-	-	-	-	-	-	-	-
1.61	1.28	-	-	-	NR	NR	NR	-	-	-
26.00	1.45	-	-	-	NR	NR	NR	-	-	-
3.28	1.48	-	-	-	-	-	-	-	-	-
2.00	1.21	-	-	-	-	-	-	-	-	-
2.20	1.72	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
1.70	1.38	-	-	-	NR	NR	NR	-	-	-
1.50	1.13	-	-	-	-	-	-	1.49	30.93	1.93
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	1.00	2.72	1.84	-	-	-	-	-	-
-	-	-	-	-	-	-	-	1.03	15.67	8.44
-	-	NR	NR	NR	-	-	-	25.00	25.00	25.00
-	-	-	-	-	-	-	-	4.00	4.00	4.00
-	-	-	-	-	1.00	1.15	1.10	-	-	-
1.91	1.37	3.92	3.92	3.92	0.68	0.80	0.80	20.00	20.00	20.00
2.15	1.62	-	-	-	-	-	-	-	-	-

TABLE 20 (Cont'd

UNIT VALUE OF CRUSHED AND BROKEN C
IN THE UNITED STATES IN 1969, BY R

Region and State	Limestone			Dolomite			Unit Va
	Low	High	Avg.	Low	High	Avg.	Low
East South Central							
Alabama	0.60	2.40	1.17	1.20	2.50	1.60	1.00
Kentucky	0.40	2.31	1.46	-	-	-	-
Mississippi	1.00	1.00	1.00	-	-	-	-
Tennessee	0.25	4.00	1.33	-	-	-	-
West South Central							
Arkansas	1.00	5.62	1.36	-	-	-	-
Louisiana	-	-	-	-	-	-	1.00
Oklahoma	0.37	3.51	1.30	NR	NR	NR	-
Texas	0.12	17.65	1.35	0.86	2.09	1.17	1.06
Mountain							
Arizona	1.25	3.23	1.64	-	-	-	-
Colorado	0.50	4.81	2.04	2.20	2.90	2.83	-
Idaho	1.10	1.10	1.10	-	-	-	-
Montana	0.53	3.08	1.24	-	-	-	-
Nevada	0.75	2.35	1.64	1.50	2.85	1.77	-
New Mexico	0.69	4.00	1.51	NR	NR	NR	-
Utah	1.00	25.00	2.25	2.66	2.66	2.66	-
Wyoming	1.00	3.64	2.11	-	-	-	-
Pacific							
California	0.57	6.00	1.07	2.00	12.53	2.91	1.37
Oregon	0.56	3.25	1.00	-	-	-	-
Washington	0.72	24.49	1.28	6.00	6.00	6.00	-
Total United States	0.12	25.00	1.45(3)	0.34	26.00	1.55(3)	1.00

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(1) "NR" indicates that value was not reported.
(2) "-" indicates no production.
(3) estimated value

TABLE 20 (Cont'd)

OF CRUSHED AND BROKEN CARBONATE STONES
TED STATES IN 1969, BY REGION AND STATE

Unit Value ($/Ton)										
ite		Shell			Calcareous Marl			Marble		
	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.
0	1.60	1.00	1.85	1.44	-	-	-	9.52	14.82	13.10
	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	1.00	1.00	1.00	-	-	-
	-	-	-	-	-	-	-	24.75	25.54	24.91
	-	-	-	-	-	-	-	NR	NR	NR
	-	1.00	2.30	1.29	-	-	-	-	-	-
	NR	-	-	-	-	-	-	-	-	-
9	1.17	1.06	1.75	1.19	1.00	1.00	1.00	20.00	20.00	20.00
	-	-	-	-	-	-	-	13.72	28.60	15.16
0	2.83	-	-	-	-	-	-	6.00	6.00	6.00
	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	5.20	36.08	31.71
5	1.77	-	-	-	NR	NR	NR	20.00	20.00	20.00
	NR	-	-	-	-	-	-	-	-	-
6	2.66	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	20.00	20.00	20.00
3	2.91	1.37	2.16	1.95	-	-	-	2.80	25.00	20.03
	-	-	-	-	-	-	-	-	-	-
0	6.00	-	-	-	-	-	-	3.70	21.63	19.47
0	1.55(3)	1.00	3.92	1.42	0.68	1.15	1.01	1.03	36.08	9.69

1. New England

The New England region produced very little crushed carbonate rock in 1969. Limestone and dolomite amounted to 0.4% of the national total, or approximately 2.4 million tons, the lowest production of any region in the United States. Some crushed marble was produced in Vermont, while one state, New Hampshire, had no carbonate rock production of any kind. Unit values tended to be high. This was probably owing to limited production under non-competitive conditions.

a. Connecticut

Limestone and dolomite production in Connecticut was estimated to be approximately 275,000 tons, all from Litchfield County quarries. No unit value was reported for limestone, but dolomite averaged $4.20/ton, much higher than the national average. Uses included soil neutralizer, lime manufacture, filler, whiting, and flux.

b. Maine

Maine produced approximately 800,000 tons of crushed limestone, with an average value of $1.32/ton. The limestone came primarily from Knox County and was used chiefly in cement manufacture. Large quantities were used also for agricultural purposes, concrete aggregate, and dense graded road base stone.

c. Massachusetts

Both limestone and dolomite were produced in Massachusetts, with the total quantity estimated to be 750,000 tons. The stone was quarried only in Berkshire County, and had unusually high average unit values, viz., $4.14/ton for limestone, and

$5.24/ton for dolomite. Dolomite production was probably quite small compared to limestone production. Chief uses were agricultural purposes, concrete aggregate, road base stone, and lime manufacture.

d. Rhode Island

Rhode Island's production of limestone was estimated to be less than 100,000 tons and came exclusively from Providence County. The average unit value of $7.57/ton was the highest value reported for limestone by any state in the country. The stone was used for ornamental purposes, flux, mineral filler, and in agricultural applications.

e. Vermont

Rutland County was the principal source of limestone and dolomite in Vermont, and the total production was approximately 525,000 tons. Perhaps as much as 500,000 tons of crushed marble were also produced,in the same county. Most of the limestone and dolomite was used as aggregate and road base stone, but large tonnages also were used for agricultural purposes, whiting, fillers, and paper manufacture. Concrete aggregate and road base stone probably consumed most of the crushed marble. The average unit value of all three materials fell within the range of $1.41 - 1.53/ton.

2. Middle Atlantic

Large quantities of crushed carbonate rocks were produced in the Middle Atlantic region in 1969. Almost 91 million tons of limestone and dolomite were produced, accounting for about 14.5% of the total national production. Individually, limestone and dolomite production represented 13.6% and 21.5% of the respective total national outputs of these two materials. Crushed marble and shell also were produced. Unit values, in general, ran somewhat higher than the national averages.

a. New Jersey

In New Jersey, an estimated 800,000 tons of limestone were quarried, primarily from operations in Sussex County. The unit value of $2.49/ton was about $1.00/ton above the national average. Agriculture was the major use, but other important uses included filler, concrete aggregate, and lime. Some crushed marble, produced in Warren County, was used for terrazzo, and its average unit value of $25.00/ton reflects the higher prices commanded by specialty markets.

b. New York

New York was one of the largest producers of crushed carbonate rocks in the United States in 1969. With over 28 million tons of limestone and 5.2 million tons of dolomite, the total of 33.5 million tons ranked New York eighth in total limestone and dolomite production among the states. Stone was quarried throughout the state with Dutchess County being the leading producer, and was used principally as an aggregate material and in cement and lime manufacture. It was also used for agricultural purposes, riprap, railroad ballast, filler, flux, and whiting. The average unit value for limestone was $1.56/ton, and for dolomite, $1.97/ton. An indeterminate amount of crushed marble, with an average value of $3.00/ton, also was produced and was used mostly for road material and agriculture.

c. Pennsylvania

In 1969, Pennsylvania ranked first both in total production of all carbonate rocks and in production of limestone in the United States. Its 47.2 million tons of limestone, combined with 9.5 million tons of dolomite, gave it a total of 56.7 million tons, which exceeded the limestone and dolomite production of every other state. This total accounted for about 9% of the national limestone and dolomite output. A small amount of shell also was produced.

The average unit value of limestone was $1.46/ton, dolomite being slightly higher, averaging $1.73/ton; no data were reported for shell. By far, the largest amount of limestone and dolomite was used as an aggregate material. Other important uses were cement and lime manufacture, flux, and agriculture.

3. East North Central

The East North Central region was the leading producer of crushed carbonate rocks in 1969. In fact, the output of limestone and dolomite was more than double that of any other region and accounted for 185.6 million tons, or about 30% of the national total. Limestone production, at 146 million tons, represented more than one-fourth of the total limestone in the United States, while dolomite, at 39.6 million tons, accounted for well over half of the national dolomite production. Significant tonnages of marl also were produced. Unit values for all materials were generally close to the national average.

a. Illinois

Illinois was the largest single producer of dolomite in the United States, with 14.7 million tons reported. Its total tonnage of limestone and dolomite, 54.8 million tons, ranked second only to Pennsylvania of all the states. Concrete aggregate and road stone consumed most of the stone; other major uses included agriculture, cement manufacture, and flux. Limestone was quarried throughout the state, while dolomite production was restricted to northern Illinois. The largest producer was Cook County. Unit values were $1.44/ton for limestone and $1.45/ton for dolomite.

b. Indiana

Indiana produced 22.9 million tons of limestone and 2.3 million tons of dolomite in 1969. Production occurred throughout the state and was used chiefly for concrete aggregate and road stone. Agricultural uses, cement manufacture and riprap also consumed significant quantities. The unit values were $1.32/ton for limestone and $1.28/ton for dolomite. Marl production, from northern Indiana, amounted to 32,000 tons and was used mainly for soil conditioning. No unit values were reported for marl.

c. Michigan

The limestone and dolomite production in Michigan was 30.7 million tons and 8.4 million tons respectively which placed it sixth in total production of all the states. Production was centered chiefly in the Upper Peninsula and in northern counties. The largest single use was as flux stone, with other major consumers being cement and lime manufacture, concrete aggregate, and road stone. Although the unit value of $1.45/ton for dolomite was in line with regional and national averages, the unit value of $1.02/ton reported for limestone, was fairly low. This probably was caused by two factors: 1) some of the largest and most efficient quarries in the United States are located in Michigan and 2) a large amount of captive stone was produced for which a low unit value may have been assigned.

The 99,000 tons of marl produced in Michigan in 1969 came primarily from quarries in the southwestern part of the state. Its major use was in agricultural applications. No unit values were reported.

d. Ohio

Ohio ranked third of all the states in total limestone and dolomite production with 50.6 million tons. Over 38 million tons of limestone were quarried, and the dolomite production of 12.5 million tons was exceeded only by Illinois. Production was reported from numerous quarries throughout the state, with Sandusky County being the leading producer. Most of the stone was used as aggregate material. Large quantities also were used for flux, cement and lime manufacture, and agricultural purposes. The average unit values were $1.54/ton for limestone and $1.48/ton for dolomite.

e. Wisconsin

Wisconsin produced a total of 15.9 million tons of limestone and dolomite in 1969. Although 14.2 million tons were classified as limestone and only 1.7 million tons as dolomite, most of the limestone was of the magnesian variety. The primary source of these materials was quarries in southern and eastern counties, with Waukesha County being the largest producer. Principal uses were aggregate and roadstone but agriculture also provided a major market. Unit values were slightly low, averaging $1.17/ton for limestone and $1.21/ton for dolomite.

4. West North Central

The West North Central region produced large tonnages of carbonate rocks in 1969. In fact, the total limestone and dolomite production of about 92.5 million tons made it the second largest producing area in the country, accounting for 14.7% of the total national output. Marl was quarried in Minnesota and some crushed marble was produced in Missouri. North Dakota reported no carbonate rock production of any kind. Most unit values did not deviate significantly from the national average.

a. Iowa

Both limestone and dolomite were quarried in Iowa, with the total output estimated to be 26.2 million tons. Limestone was produced chiefly in the eastern half of the state, while dolomite production was recorded in northern and eastern counties. Madison County was the largest producer. Most of the stone was used for concrete aggregate and road stone with other important uses being agriculture and cement manufacture. Limestone averaged $1.49/ton, while dolomite was slightly higher at $1.72/ton.

b. Kansas

Kansas produced 15.3 million tons of limestone in 1969, predominantly from quarries in the eastern part of the state. Johnson County was the largest producer. The stone was used chiefly for concrete aggregate, road stone, and cement manufacture, with lesser amounts required for agricultural purposes, riprap, flux, railroad ballast, and whiting. The average unit value for limestone was $1.40/ton.

c. Minnesota

Limestone and dolomite production in Minnesota totaled 4.1 million tons of which 3.3 million tons were limestone.

Quarrying was done primarily in the southeastern corner of the state, with Blue Earth County being the leading producer. Concrete aggregate and road stone consumed most of the output. Limestone and dolomite averaged $1.32/ton and $1.38/ton respectively. An undisclosed amount of marl was produced in central Minnesota and used exclusively for agricultural purposes. No unit values were reported.

d. Missouri

Missouri's total production of limestone and dolomite was the largest of any state in the region, and ranked Missouri as the fourth leading producer in the nation. Total production was 41.2 million tons of which only 932,000 tons were dolomite. Production occurred throughout the state, with the leading area being around St. Louis. The two largest markets for this were concrete aggregate and road stone but agriculture, cement manufacture, and riprap also consumed large quantities. Limestone was valued at an average of $1.39/ton while dolomite averaged $1.13/ton. Some crushed marble, averaging $1.93/ton, also was produced and used for terrazzo and exposed aggregate.

e. Nebraska

About 4.7 million tons of limestone were quarried in Nebraska in 1969. Virtually all production came from the southeastern counties. Riprap, concrete aggregate and road stone were the major uses. The average unit value was $1.87/ton.

f. South Dakota

South Dakota produced only 989,000 tons of limestone in 1969, all from three western counties. The stone avaraged $1.22/ton and was used chiefly for concrete aggregate, road stone, and cement.

5. South Atlantic

Large quantities of carbonate rocks of all types were produced in the South Atlantic region in 1969. Limestone and dolomite production totalled 87.5 million tons, of which 80.9 million tons were limestone. Dolomite was quarried only in two of the northernmost states in the region -- Virginia and West Virginia. The total limestone and dolomite represented 14.0% of the national production of these materials.

Shell was produced in Maryland, Virginia, and chiefly in Florida. Production of marl was reported in South Carolina and Virginia. Crushed marble came from Georgia, Maryland, North Carolina, and Virginia. Delaware reported no crushed carbonate rock production.

For the most part, unit values in the region did not deviate very much from the national averages. Shell and marble, though, tended to be high.

a. Florida

Florida was the largest limestone producing state in the region with 40.7 million tons reported. Nationwide it ranked second only to Pennsylvania in limestone production and fifth in the total production of all types of carbonate rocks. Two types of limestone, hard-rock and soft-rock, were quarried, with soft-rock limestone predominating. This latter material was used chiefly for dense graded road base stone, agricultural purposes, and lime manufacture. Hard-rock limestone was used mainly as concrete and bituminous aggregates. No data were available on relative costs, but it is estimated that soft-rock limestone was valued at roughly $1.00/ton, while hard-rock limestone averaged around $1.50/ton. The overall average unit value for all limestone was $1.31/ton. Production was reported throughout the state, with Dade County being the leading producer.

b. Georgia

Georgia produced 4.3 million tons of limestone in 1969. Stone came primarily from quarries in the western part of the state, with Early, Floyd, and Whitfield counties being the leading producers. Primary use was concrete and road stone; other uses included agriculture, cement manufacture, riprap, and flux. The average unit value was $1.50/ton. Some crushed marble, averaging $8.44/ton, was produced in northwestern Georgia. It was used primarily for agricultural stone, fillers, and whiting.

c. Maryland

Limestone production in Maryland amounted to 9.8 million tons in 1969. Quarrying was chiefly in the northern and central parts of the state. Most of the stone was used for construction purposes but small amounts also were used for agriculture, cement manufacture, and metallurgical flux. The average value was reported to be $1.57/ton. Undisclosed quantities of shell and crushed marble were produced. No unit values were reported for shell, but marble averaged a very high $25.00/ton.

d. North Carolina

An estimated 4.5 million tons of limestone were quarried in North Carolina. Production was reported in western counties and in an area along the Atlantic coast. Chief uses were as aggregates and road base material and the average unit value was $1.62/ton. Also produced was some crushed marble, valued at $4.00/ton.

e. South Carolina

South Carolina produced an estimated 1.9 million tons of crushed limestone. Quarrying was done in only three counties -- Berkeley, Cherokee, and Dorchester. Primary markets for the stone, which averaged $1.51/ton, were cement manufacture and agricultural purposes. Marl, averaging $1.10/ton, was produced in Dorchester and Orangeburg Counties.

f. Virginia

Virginia produced all types of carbonate rocks in 1969, with limestone and dolomite combined totaling 17.8 million tons. At 4.4 million tons, the state was the largest dolomite producer in the South Atlantic region. The stone came mainly from quarries in western Virginia and was valued at $1.52/ton for limestone, and $1.37/ton for dolomite. Its principal uses were as concrete aggregate and road stone. Other important uses were cement and lime manufacture, agricultural dressing, and flux.

An undisclosed quantity of shell was produced in Isle of Wight County. It was used for agricultural purposes and had a unit value of $3.92/ton, almost three times the national average for shell.

Total marl production was not reported, but the material averaged $0.80/ton in value. Its uses included cement manufacture and agriculture. Crushed marble from Rockingham County was valued at $20.00/ton.

g. West Virginia

Limestone and dolomite production in West Virginia amounted to 8.4 million tons of which 6.2 million tons were limestone. Production came chiefly from quarries in northeastern West Virginia. Major uses were concrete aggregate and road stone, flux, railroad ballast, agriculture, and cement and lime manufacture. Both limestone and dolomite averaged $1.62/ton.

6. East South Central

Production of all types of carbonate rocks were reported in the East South Central region in 1969. The combined production of limestone and dolomite was 81.3 million tons, accounting for 13.0% of the national production. Dolomite was quarried only in Alabama, and amounted to slightly more than 2.1 million tons. Alabama was also the only producer of shell in the region. Marl production was reported in Mississippi, while crushed marble was produced in Alabama and Tennessee. Unit values were mostly in line with the national averages, with a few exceptions. Average unit values for marble were high. Also, in the two southernmost states of the region, Alabama and Mississippi, unit values for limestone were low.

a. Alabama

Other than marl, all types of carbonate stones were produced in Alabama in 1969. A total of 17.8 million tons of limestone and dolomite were quarried; 15.6 million tons of this were limestone. Quarries were scattered throughout the state, but most of the limestone came from operations in the northern half of the state. Dolomite production was confined to three counties in central Alabama. The average unit values were $1.17/ton for limestone and $1.60/ton for dolomite. Most of the stone was used for concrete aggregate and roads but other important uses were cement and lime manufacture, agricultural purposes, flux, and riprap.

Shell produced in Mobile County averaged $1.44/ton, and was used in road construction and cement manufacture. Crushed marble production was reported in Talladega County and totalled 632,000 tons. This material, averaging $13.10/ton, was used for fillers and whiting.

b. Kentucky

Kentucky produced only limestone, but the total tonnage of almost 30.2 million tons ranked it eighth nationwide. Numerous quarries were in operation throughout the state, with the leading counties being Livingston, Christian, and Jefferson. The stone averaged $1.46/ton and was used chiefly as concrete aggregate and road material. Other important uses were agricultural stone and riprap.

c. Mississippi

An estimated 300,000 tons of limestone were produced in Mississippi. The material was quarried in only three counties and averaged $1.00/ton. An undisclosed amount of marl also was quarried, and had the same average value. No information was found regarding end-uses of either material.

d. Tennessee

Tennessee was the leading producer of limestone in the region in 1969, with a total of 33.1 million tons. It ranked sixth in the country in total limestone produced. Numerous quarry operations were scattered throughout the central and eastern parts of the state. The material had an average unit value of $1.33/ton and was used primarily for concrete and roads. Agriculture and cement manufacture were other major uses.

Some marble was produced in eastern Tennessee and used for terrazzo, mineral food, and agricultural purposes; it had a high unit value of $24.91/ton.

7. West South Central

Limestone and dolomite production in the West South Central region was about 58.3 million tons, comprising 9.3% of the national total. Dolomite was quarried only in Oklahoma and Texas. Louisiana was the only state reporting no production of either material;however, it was the largest producer of shell in the United States. Shell also was produced in significant quantities in Texas. In fact, the total shell represented over 83% of the national production of this material. Crushed marble was quarried in Arkansas and Texas, and the latter state was the only source of marl in the region. Unit values were generally low, except for marble.

a. Arkansas

Arkansas produced 5.7 million tons of limestone in 1969 from quarries located primarily in the northern portion of the state. The stone was used for concrete and road aggregate, riprap, and cement and lime manufacture. Its average unit value was $1.36/ton. Crushed marble was produced in Independence County, but no other information is available on this material.

b. Louisiana

As previously mentioned, shell was the only carbonate material produced in Louisiana in 1969. Total output was over 9.2 million tons and averaged $1.29/ton in value. Production was from four counties in southern Louisiana, and the material was used primarily for concrete aggregate, road construction, and cement and lime manufacture.

c. Oklahoma

Oklahoma produced an estimated 16.3 million tons of limestone and dolomite. Production of limestone came from numerous quarries spread predominantly throughout the eastern half of the state. Dolomite was quarried only in Johnston County. Large quantities were used for concrete and road aggregate and for agricultural purposes. On the average, limestone was valued at $1.30/ton. No unit values were reported for dolomite.

d. Texas

Texas was the largest producer of limestone and dolomite in the region, with 36.3 million tons produced in 1969. It ranked seventh nationally in production of these rocks. In addition, shell, marl, and marble also are quarried. The state was the second largest producer of shell in the nation.

Limestone was quarried throughout the state, but chiefly in central Texas. Dolomite was produced only in Burnet and El Paso Counties. Limestone averaged $1.35/ton, while the unit value for dolomite was $1.17/ton.

Shell was dredged along the Gulf Coast. Total output was almost 7.2 million tons and the material averaged $1.19/ton in value.

Undisclosed amounts of marl and crushed marble were quarried in Texas. Marl, from Bexar County, was valued at $1.00/ton. Crushed marble, from quarries in Burnet and Llano Counties, had a high unit value of $20.00/ton.

The principal uses of crushed stone were concrete aggregate and road stone, cement and lime manufacture, and riprap. Crushed marble was used for terrazzo chips, and roofing and other special aggregates.

8. Mountain

The Mountain region produced a relatively small amount of crushed carbonate rocks in 1969. Limestone and dolomite production amounted to only 10.7 million tons and represented just 1.7% of the national total. Marl was quarried in Nevada, and five states produced small amounts of marble. Unit values were variable, but in general tended to be relatively high.

a. Arizona

Arizona produced over 2.3 million tons of limestone in 1969 from quarries throughout the state. The material averaged $1.64/ton and was used chiefly for concrete aggregate, and cement and lime manufacture. Crushed marble was produced in southern Arizona and valued at $15.16/ton.

b. Colorado

Limestone and dolomite production in Colorado amounted to an estimated 1.65 million tons. Limestone had an average unit value of $2.04/ton, while dolomite averaged $2.83/ton, both well above the national figures. Crushed marble, from central Colorado quarries, was valued at $6.00/ton. Major uses were cement manufacture, flux, riprap, road and concrete aggregate, lime manufacture, and surface treatment aggregate.

c. Idaho

Little limestone was quarried in Idaho in 1969. An estimated 250,000 tons were produced in three countries. Virtually all of the output was used in sugar refining and cement manufacture. The material had a low unit value of $1.10/ton.

d. Montana

Production of limestone in Montana amounted to over 1.4 million tons. Most of the stone came from quarries in southwestern counties. The material, which averaged $1.24/ton, was used chiefly for cement and lime manufacture, sugar refining, and metallurgical purposes. A small amount of crushed marble, used in concrete, whiting, roofing granuales, and terrazo, was also produced in southwestern Montana. It had an exceedingly high average unit value of $31.71/ton.

e. Nevada

Nevada produced a variety of carbonate materials, but total output was quite small. Approximately 1.0 million tons of limestone and dolomite were quarried from operations in four widly separated counties. Major uses were sugar refining, cement and lime manufacture, flux, and for agricultural purposes. Both materials had somewhat high average unit values. Limestone and dolomite averaged $1.64/ton and $1.77/ton respectively.

Marl, for use as mineral fillers, was quarried in Nye County but no unit values were reported. A small amount of crushed marble, produced in Mineral County and valued at $20.00/ton, was used for terrazzo.

f. New Mexico

New Mexico produced nearly 1.0 million tons of limestone from quarries scattered throughout the state and a small amount of dolomite was produced from one quarry in Grant County. Chief uses were dense graded road base stone and cement manufacture. Other uses were flux, lime manufacture, and various construction purposes. The only unit values reported were for limestone, which averaged $1.51/ton.

g. Utah

With approximately 2.4 million tons of limestone and dolomite, Utah ranked as the leading producer of these materials in the Mountain region in 1969. Stone was quarried primarily in the northern part of the state, with dolomite production only from Tooele County. Uses included lime and cement manufacture, flux, agricultural applications, and aggregates. Unit values were high: limestone averaged $2.25/ton and dolomite was even higher, at $2.66/ton.

h. Wyoming

Wyoming reported only 649,000 tons of limestone in 1969. Most of the production came from southeastern counties and was used for sugar refining, cement and lime manufacture, and construction purposes. It was valued at $2.11/ton. Some crushed marble was produced in Platte County and valued at $20.00/ton.

9. Pacific

The Pacific region produced about 18.8 million tons of limestone and dolomite in 1969, most of which came from California. Total production represented only 3.0% of the national output. Shell also was produced in California, and this state, in addition to Washington, reported production of crushed marble. Averaged unit values were somewhat erratic, being low for limestone but quite high for the other materials, in comparison to national average values.

a. California

Total limestone and dolomite production from California in 1969, from quarries throughout the state, amounted to an estimated 17.4 million tons. By far, the single major use was in cement manufacture. However, substantial quantities also were consumed in lime manufacture, flux, agricultural purposes, and aggregate material. Limestone had a very low average unit value of $1.07/ton. On the other hand, dolomite value was very high, at an average of $2.91/ton.

Shell, dredged from San Francisco Bay, was valued at $1.95/ton and used in cement manufacture and as poultry grit. Marble was quarried in three counties and averaged $20.03/ton in value. It was used as an aggregate material and also for specialty uses.

b. Oregon

Oregon produced a small amount of crushed limestone, estimated to be about 350,000 tons. The stone was quarried in only two counties, Baker and Multnomah, and averaged just $1.00/ton in value. Cement and lime manufacture, sugar refining, agriculture, and the paper and metallurgical industries consumed the bulk of the material.

c. Washington

Total production of limestone and dolomite in Washington was slightly more than 1.0 million tons, of which 749,000 tons were limestone. Quarrying was done primarily in the northern counties, with dolomite production being reported only in Stevens County. The primary uses of stone were cement and lime manufacture, agricultural purposes, and in the paper and metallurgical industries. Limestone was valued at $1.28/ton. Dolomite had an exceedingly high unit value of $6.00/ton. Stevens County reported production of crushed marble, averaging $19.47/ton, which was used as terrazzo and for various other construction purposes.

D. Quarries

Appendix A contains a tabulation of quarries which produce limestone, dolomite, shell, marl, and marble. This listing was compiled from information supplied by the United States Bureau of Mines and includes virtually all quarries in the United States which produced crushed carbonate stone in 1969. For each material, the number of quarries is summarized by county and state. This has been provided to help the reader who is interested in a particular area to determine qualitatively the extent of production in and around that area.

IX. TRANSPORTATION

A. Methods Employed

Table 21 indicates, by state, the modes of transportation used to ship crushed stone in 1969. Although the data apply to all crushed stone, they should be similar for carbonate rocks, since these constitute about 75% of all crushed stone in the United States. The table was derived from information furnished by the United States Bureau of Mines. The column headed "Other or Unspecified" includes stone transported by conveyors and similar methods, stone used at the quarry site by captive producers, and shipments not specified by individual producers.

Nationally, truck transportation dominated in the movement of crushed stone, accounting for about 72% of all stone shipped. It was the most commonly used mode in most states, and accounted for virtually all stone shipped in several areas, e.g., Iowa.

Various types of trucks, ranging in capacity up to 50 tons, are used to transport stone. The most prevalent types employed are the rear-dump truck and the blower truck. The latter is a closed type which can quickly unload by pneumatic discharge.

Because of the abundance of limestone deposits and quarries, many users are near a source of supply. Trucks are ideally suited to this type of short haul. The federal highway program and the construction and improvement of secondary roads, coupled with the development of larger and more reliable trucks, have extended their use. Trucks provide flexibility, and since loading can be done quickly, they can provide fast, same-day delivery. Unloading facilities at the consumer's plant are minimal. Their relatively low capacity, however, can be a drawback if large quantities of limestone are required, as would be the case with the larger power plants.

TABLE 21

PERCENT OF CRUSHED STONE SHIPPED BY VARIOUS METHODS IN 1969

State	Method of Transportation			
	Truck	Railroad	Waterway	Other or Unspecific
Alabama	NA	NA	NA	NA
Arizona	63.1	7.0	-	29.9
Arkansas	40.8	22.4	-	36.8
California	75.6	9.4	3.0	12.0
Colorado	72.5	24.2	-	3.3
Connecticut	67.0	13.7	18.7	0.6
Delaware	-------------- No Production ----------------			
Florida	76.1	21.0	1.8	1.1
Georgia	75.1	24.9	-	-
Idaho	NA	NA	-	NA
Illinois	91.3	7.4	1.3	-
Indiana	88.7	5.2	6.1	-
Iowa	96.9	2.9	0.2	-
Kansas	72.2	9.3	3.0	15.5
Kentucky (1)	76.1	5.1	18.6	0.2
Louisiana (1)	NA	NA	>90.0	-
Maine	NA	NA	-	NA
Maryland	90.1	0.9	-	9.0
Massachusetts	93.8	2.6	-	3.6
Michigan	25.8	1.0	73.2	-
Minnesota	78.9	13.7	7.4	-
Mississippi	NA	-	-	NA
Missouri	72.2	6.9	7.4	13.5
Montana	93.8	6.2	-	-
Nebraska	18.3	6.1	-	75.6
Nevada	89.4	10.6	-	-
New Hampshire	NA	NA	-	-
New Jersey	NA	NA		-
New Mexico	NA	-	-	NA
New York	53.6	5.2	22.1	19.1
North Carolina	91.2	8.4	0.4	-
North Dakota	-	-	-	100.0
Ohio	59.4	21.7	5.6	13.3
Oklahoma	68.5	15.3	-	16.2
Oregon	96.6	2.7	0.7	-
Pennsylvania	74.0	12.8	0.1	13.1
Rhode Island	NA	-	-	-
South Carolina	70.4	24.5	-	5.1
South Dakota	39.3	13.1	-	47.6
Tennessee	85.9	9.8	2.2	2.1
Texas	52.5	14.3	13.4	19.8
Utah	11.8	69.6	-	18.6
Vermont	95.9	3.9	-	0.2
Virginia	76.0	17.4	1.2	5.4
Washington	88.4	4.9	5.1	1.6
West Virginia	43.3	32.4	1.3	23.0
Wisconsin	96.3	3.7	-	-
Wyoming	35.7	60.2	-	4.1
U.S. Overall	71.6	11.3	8.8	8.3

NA - Data are not available

(1) - Percentages are based on part of the crushed stone production. Complete data are lacking.

Rail transportation was employed to move over 11% of all crushed stone, nationally. It was particularly significant in the southeastern United States and in several of the Rocky Mountain states. Although not the most commonly employed method in the major limestone producing areas in the north and east, rail nevertheless was used to haul millions of tons of stone in this region.

The eastern half of the United States is densely covered with rail lines, with main lines extending in all directions and interconnecting at many points. This is not true in the west. Beyond Duluth, Omaha, Oklahoma City, and Fort Worth, lines thin out considerably, becoming sparse in most regions of the Rocky Mountains. Main lines generally run east-west and interconnect at few places. There are few major rail centers compared to the eastern and central states.

Hopper cars and gondolas are commonly used to haul limestone. Hoppers may be either open or closed top, and discharge by either gravity or pneumatic transfer. Jumbo cars, having capacities up to 250 tons or more, are available, but most stone is shipped in 60 to 100 ton capacity cars.

Rail shipment, rather than truck haul, is generally used for longer distances. To take maximum advantage of this mode of transportation, direct rail connections via branch lines, spurs, and sidings are necessary between stone producer and consumer. In addition, since carload quantities are desirable, larger inventories and more extensive storage facilities are required on both ends. Where limestone shipments are very large, the unit train concept could be employed.

Many power plants have existing rail facilities to haul in coal. For these plants, particularly the larger ones with a potentially high demand for limestone, rail transportation may be the logical choice. Rail haul is indicated also in cases where no nearby source of limestone exists.

As shown in Table 21, about 9% of all crushed stone was moved by water. In Louisiana and Michigan, most of the stone produced was hauled by this method since the major limestone deposits are near water. It was also an important mode in the New York-Connecticut area and in Kentucky.

Figure 17 shows the commercially navigable inland waterways in the United States. Almost all are located in the eastern half of the country. The most important waterways are the Great Lakes, the Mississippi River system, and the Gulf Intercoastal Waterway. The Great Lakes are strategically located in a high-producing limestone region. The Mississippi River system is a vast, sprawling network of rivers which reach northward to Minneapolis-St. Paul and Chicago, eastward to Pittsburgh and Knoxville, and westward to Sioux City, Iowa and Catoosa, Oklahoma. The Missouri River and the Mississippi River below St. Louis are open rivers. Other waterways in the system have been improved for navigation through the use of locks and dams. The Gulf Intercoastal Waterway is a series of connected bays, sounds, tidal estuaries, and land cuts which extend from St. Marks, Florida to Brownsville, Texas.

Barges commonly are used to haul stone on rivers and along the Gulf Intercoastal Waterway. They may be either the open-hopper or covered-hopper type. Capacities vary, but most crushed stone is shipped in 1200-1400 ton barges. Usually, individual barges are lashed together to form an integrated tow which is moved by a single towboat. Unloading is done by clamshell bucket or by an air system.

On the Great Lakes, stone generally is shipped in large cargo vessels. Bulk carriers and self-unloaders now in use have capacities of up to 29,000 tons with even larger capacity ships being planned for the future. Bulk carriers are unloaded by shore-based equipment while self-unloaders, having a long, movable boom equipped with a conveyor, require no such facilities.

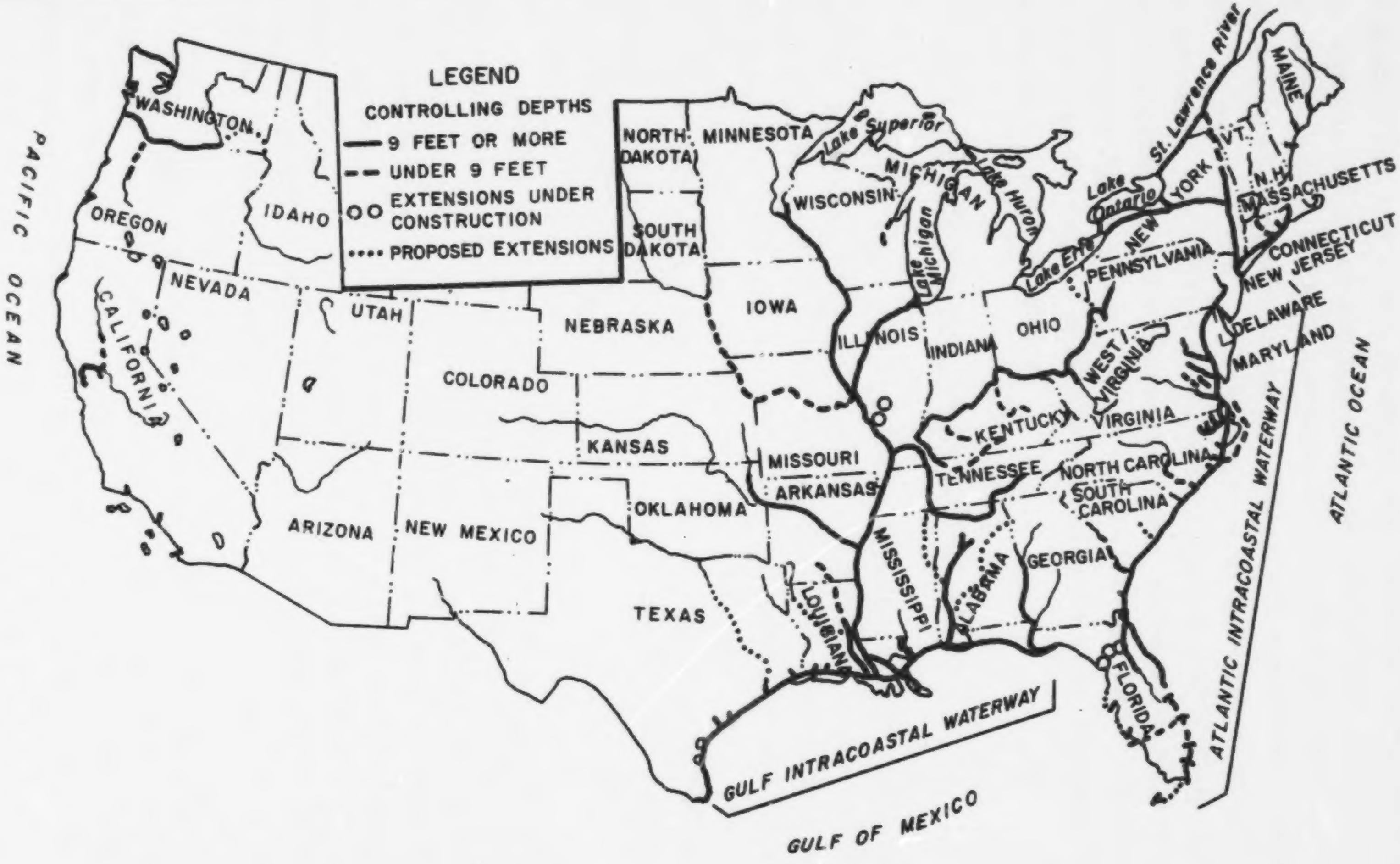

LEGEND
CONTROLLING DEPTHS
9 FEET OR MORE
UNDER 9 FEET
EXTENSIONS UNDER CONSTRUCTION
PROPOSED EXTENSIONS
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
GULF INTRACOASTAL WATERWAY
ATLANTIC INTRACOASTAL WATERWAY
St. Lawrence River
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MARYLAND
DELAWARE
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
VT.
N.H.
MAINE

FIGURE 17

COMMERCIALLY NAVIGABLE INLAND WATERWAYS OF THE 48 CONTIGUOUS STATES

(REPRINTED FROM U.S. BUREAU OF MINES INFORMATION CIRCULAR NO. 8431)

Barge or boat shipment normally is used for longer distances and where both the stone producer and consumer are located on or near water. It is comparatively slow and, since vessel capacities are high, requires large inventories and storage facilities. It also requires adequate docks and unloading equipment. Some northern waters, e.g., the Missouri and upper Mississippi Rivers, and parts of the Great Lakes, are closed to navigation during winter months, thereby necessitating a large stockpile of stone at the consumer's plant. Some of the larger power plants which are located on inland waters might be economically supplied with limestone by boat or barge.

B. Factors Influencing Transportation Costs

Obviously, the selection of a transportation method for hauling limestone to a power plant is limited by the location of both quarry and utility, and by the routes available. Since the delivered cost of the stone is determined by adding the transportation charge to the quarry cost, and since many factors have an effect on transportation rates, it is very difficult to predict accurately what the delivered cost of stone would be for a specific case.

Shipment of stone is under varying degrees of federal and state control. Most interstate shipment by rail and truck is regulated by the Interstate Commerce Commission (ICC) which requires carriers to publish a set of tariffs. Interstate movement by barge and boat, however, is largely exempt from ICC regulations. Several states have agencies which control intrastate shipment. Usually, intrastate transportation is significantly cheaper than interstate.

The type of equipment used to haul the stone also has an effect on freight rates. Open type trucks, rail cars, and barges are cheaper than covered types. In many instances, there is a shortage of equipment and this has an adverse effect on freight charges. However, many of the larger quarries, particularly, operate their own vehicles and this can result in reduced rates through more efficient utilization of the equipment. Loading facilities at the quarry and unloading facilities at the power plant must be adequate for the method employed. Any increased hauling which the shipper must do will increase costs.

Large single-shipment volumes, as well as large annual volumes and regularity of movement frequently result in rate reductions. This is not always true, however. For example, in some states where rates are under control of a state commission, tonnages have no bearing on cost.

Because of the relatively large quantities potentially required by most power plants, it is expected that limestone usually would be hauled in unit lots, i.e., in truckload, carload, bargeload, or boatload quantities. However, shipments of less than a unit lot sometimes may be considered, as, for example, in cargo vessels on the Great Lakes since, in this case, huge tonnages are required to qualify as a unit lot. Rates for shipments of less than a unit lot are much higher than for lot-sized quantities. The number of vehicles used for a single shipment also has an influence on rates.

Route conditions are important. Shipments in mountainous areas are more costly than in flat, level regions. Costs are usually higher for hauls through heavily populated areas because the running time of the vehicle is increased. Truck rates are influenced by the type and condition of roads. Rail shipment is cheapest when single main lines are used. When branch lines are used, or when two or more railroads are involved, costs will be higher. Barge rates are affected by the allowable draft, the chamber size of locks, and congestion at locks caused by high traffic density.

Dead-running time of the vehicles also has an influence on freight rates. In instances where the shipper can obtain a profitable back-haul, substantially lower rates may be obtained than if the vehicles return empty.

In many cases, commodity rates have been established on a point-to-point basis for specific items. For instance, rail rates have been set in the midwest for flux stone (limestone) used in iron and steel manufacture. They are much lower than the rates that would otherwise apply, and it is possible that limestone shipped to power plants in the same areas might qualify for these rates.

Intermodal transportation, i.e., shipment by more than one method, sometimes affords the lowest overall cost. For example, a quarry adjacent to water might be able to barge stone to within a few miles of a power plant at a low cost. The stone could then be transferred to trucks which would complete the haul.

Competition between carriers is often keen. Depending on other factors, this could result in large reductions in transportation costs through negotiations. In addition, shippers will often modify their rates to reflect changes in the traffic volumes. New commodity rates may be established if justified.

C. Transportation Rates

Application of the factors discussed in the preceeding section results in a wide range of transportation rates. This variation in rates obscures differences between regions and states and makes it difficult to establish average values, even within a single state. Anomalies, such as long hauls being less costly than short hauls, are common. Consideration of these factors suggests that, rather than use average values, it would be more appropriate to describe transportation rates by a range of values which would include most rates actually encountered.

Figures 18, 19, and 20 present transportation rates for truck, rail, and waterway respectively. Based primarily on data obtained from various limestone producers, the rates are shown as a range of values and as a function of distance. For truck movement, rates vary from 5.0 - 10.0¢/ton-mile, for 10 mile shipments, to 2.0 - 5.0¢/ton-mile for hauls of 100 miles. Rail rates range from 4.5 - 6.0¢/ton-mile, at 10 miles, to 0.75 - 1.5¢/ton-mile at 250 miles. Shipment via waterway decreases in cost from 0.9 - 1.5¢/ton-mile, at 20 miles, to 0.25 - .50¢/ton-mile at 500 miles.

The lower curves shown in Figures 18, 19, and 20 correspond to rates which could be obtained under favorable conditions; i.e., high volume movement, periodic shipments in lot-sized quantities, intrastate shipment or commodity rates, etc. The upper curves correspond to unfavorable conditions. In a few cases, rates may be outside the ranges indicated.

The range of distances for which rates are shown represents the typical operating range for the particular mode of transportation. Trucks are frequently used for distances up to about 50 miles and, less commonly, for hauls of 100 miles. Beyond 100 miles, rail shipment is customarily employed. Because of the abundance of limestone quarries, it is expected that rail shipment for more than 250 miles rarely will be necessary. Waterway transportation is usually the cheapest of the three methods and in some cases this could justify shipments of a few hundred miles. No rates are shown for very short hauls since they are infrequent. Where they do occur, a flat fee is usually charged.

D. Availability of Equipment

In most areas, there is an adequate supply of trucking equipment. Truck availability is occasionally a problem in some areas particularly when large volume movements are involved. If adequate notice is given, sufficient trucks usually can be obtained. It is not expected to be a problem in hauling limestone to power plants.

FIGURE 18

TRUCK TRANSPORTATION RATES FOR SHIPMENTS
OF
CRUSHED STONE IN THE UNITED STATES

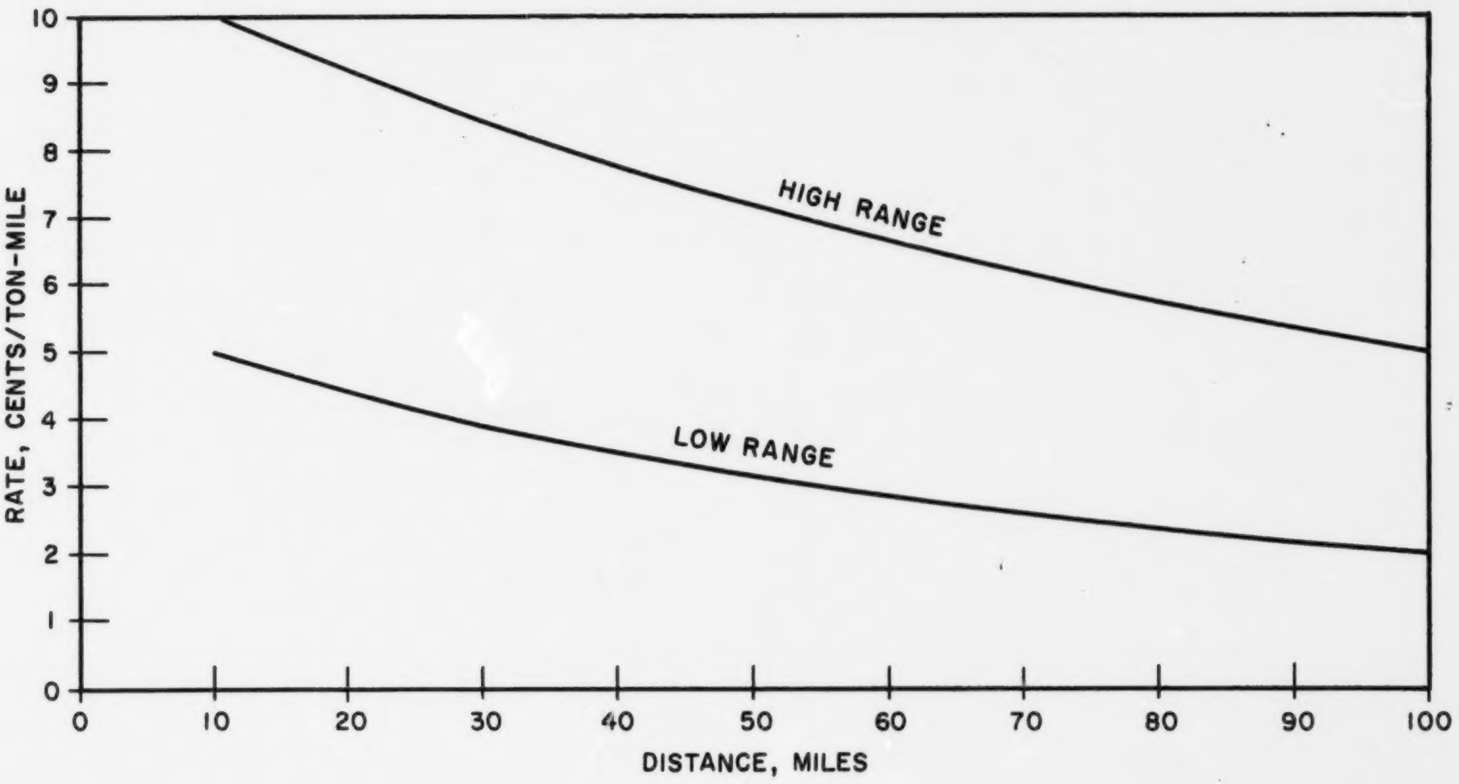


FIGURE 19

RAIL TRANSPORTATION RATES FOR SHIPMENT
OF
CRUSHED STONE IN THE UNITED STATES

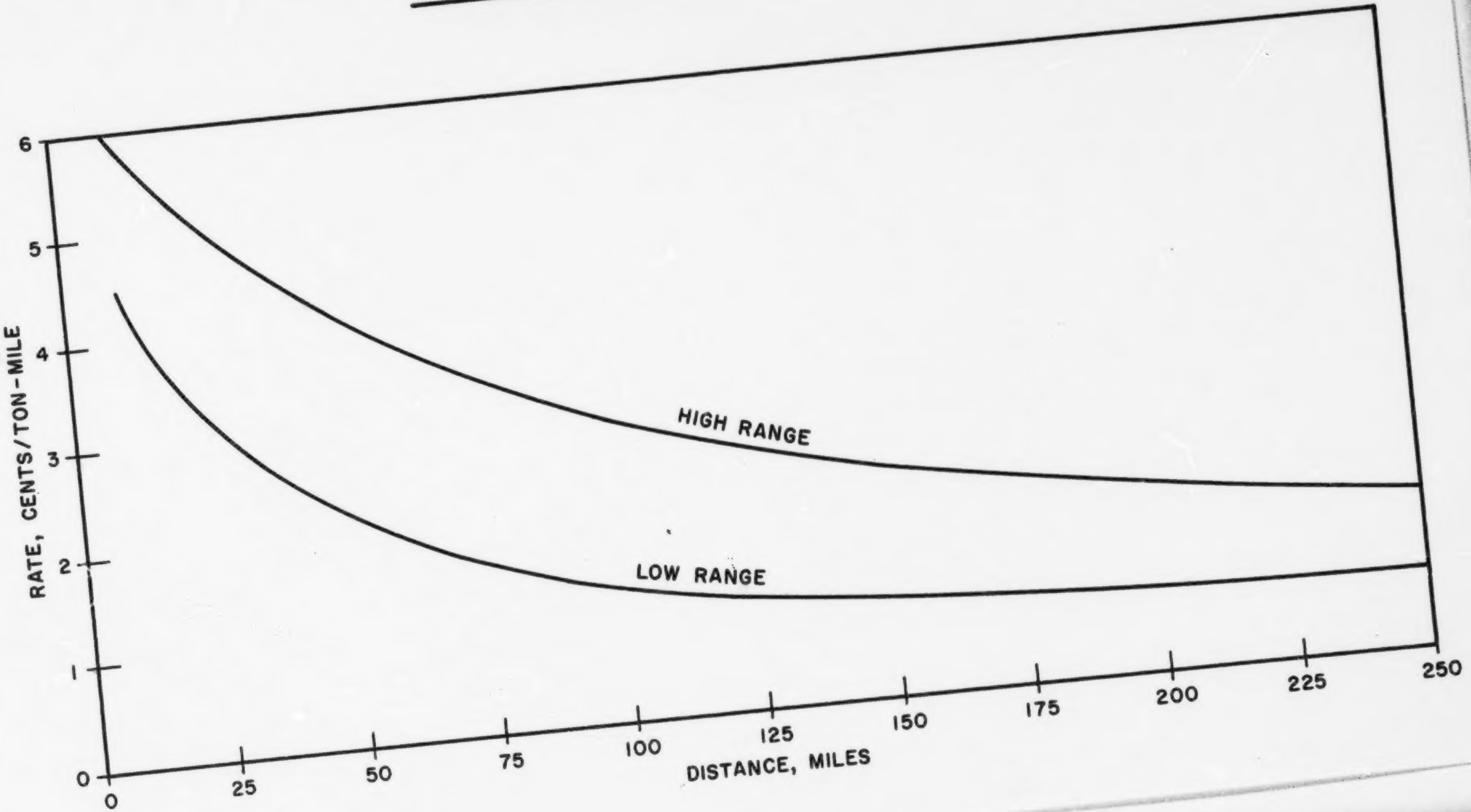
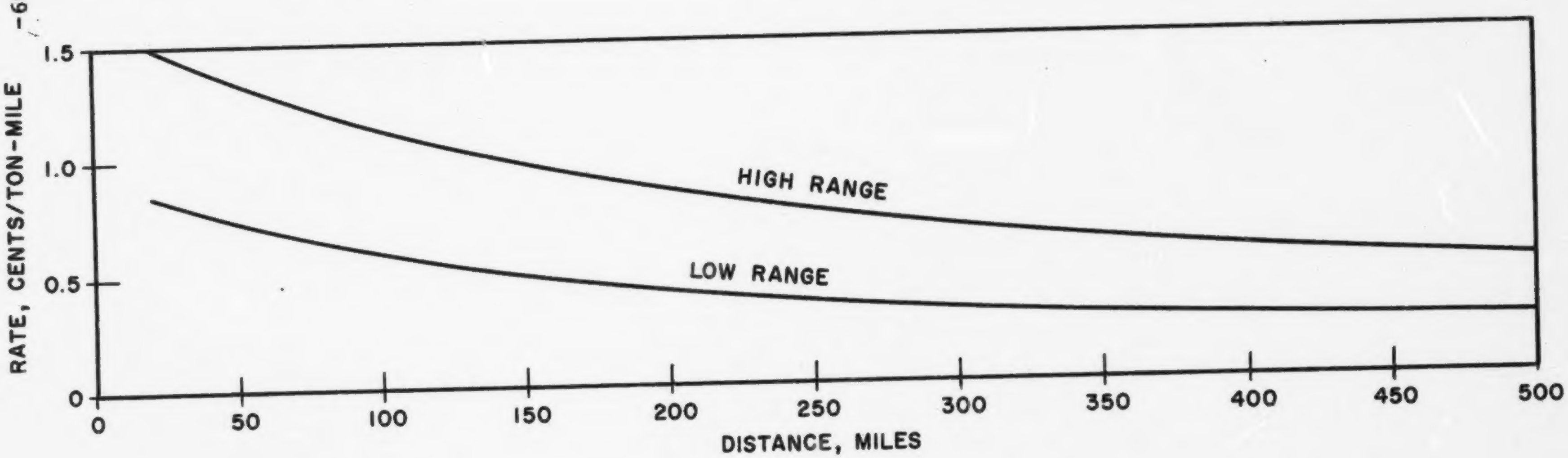


FIGURE 20

WATERWAY TRANSPORTATION RATES FOR SHIPMENT OF CRUSHED STONE IN THE UNITED STATES



By contrast, most sections of the country are confronted with a shortage of railroad cars. The situation is particularly bad in many parts of the eastern, midwestern, and southern sections of the country, where the shortage of open top hoppers and gondolas is severe at times. Seasonal demands for open top cars for other commodities frequently limits the availability of cars for hauling limestone. In some cases, shippers must repair and clean cars before loading, which increases the cost. The situation should be better for moving limestone to power plants, however, since the limestone demand is known and shipments, therefore, could be scheduled well in advance.

Availability of boats for stone shipments on the Great Lakes is normally no problem. Barges are sometimes in short supply, particularly in the peak summer season. However, they can usually be obtained if the requirements are known well ahead of time.

E. Delivered Price of Limestone

In order to determine what the actual cost of limestone would be for a power plant, a representative list of 37 of the larger power plants was made. All of the plants selected have capacities exceeding 200 MW and were chosen to give a representative sampling of locations and conditions; i.e., urban, rural, on water, inland, mountainous terrain, etc. Most of the plants are located in the eastern half of the United States, where the major coal- and oil-fired power plants are found.

Limestone producers were asked to estimate the base price of stone and the transportation charges to these locations. It was assumed that a high calcium limestone (>95% $CaCO_3$) would be required.

The results of this inquiry are shown in Table 22. The delivered price of limestone ranges from a low of $1.95/ton for the Riverside plant in Iowa to a high of over $13/ton for the Leland Olds plant. In cases where no reply was obtained for

TABLE 22

DELIVERED PRICE OF HIGH-CALCIUM LIMESTONE TO SELECTED POWER PLANTS

Power Plant	Location	Delivered Price ($/Ton)
Benning	Washington, D.C.	4.50*
Gorgas	Gorgas, Alabama	3.23
Cherokee	Denver, Colorado	6.36
J. McDonough	Cobb County, Georgia	4.50
Devon	Millford, Connecticut	4.50*
Fisk	Chicago, Illinois	2.40
R.S. Wallace	East Peoria, Illinois	3.30
Will County	Lockport, Illinois	3.30
D.H. Mitchell	Gary, Indiana	2.65
Wabash	Terre Haute, Indiana	2.25 (75-94% $CaCO_3$)
Riverside	Iowana, Iowa	1.95
Lawrence	Lawrence, Kansas	3.66
Cane Run	Louisville, Kentucky	3.00
Elmer Smith	Owensboro, Kentucky	3.72
Riverside	Baltimore, Maryland	3.85
Edgar	N. Weymouth, Massachusetts	4.50*
L Street	Boston, Massachusetts	4.50*
Delray	Detroit, Michigan	2.40
High Bridge	St. Paul, Minnesota	3.00
Hawthorn	Kansas City, Missouri	4.60
Sioux	West Alton, Missouri	3.10
Essex	Newark, New Jersey	4.50*
Port Jefferson	Port Jefferson, New York	4.50*
Waterside	New York, New York	4.50*
Allen	Belmont, North Carolina	5.39
Leland Olds	Stanton, North Dakota	13.20
Tidd	Brilliant, Ohio	3.80
Miami Fort	North Bend, Ohio	2.45
Acme	Toledo, Ohio	2.45
Horseshoe Lake	Horseshoe Lake, Oklahoma	8.00
Elrama	Elrama, Pennsylvania	5.55 (92% $CaCO_3$)
Schuylkill	Philadelphia, Pennsylvania	4.50*
Wateree	Rockland City, South Carolina	3.90 (88% $CaCO_3$)
Bull Run	Oak Ridge, Tennessee	4.24
Cabin Creek	Cabin Creek, West Virginia	6.00
Kammer	Captina, West Virginia	4.00 (80% $CaCO_3$)
Lakeside	St. Francis, Wisconsin	2.60

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* - Source of stone is outside of U.S. (Bahamas)

high calcium stone, the purity of the stone is indicated in parentheses after the delivered price.

More than half of the plants listed could be supplied with limestone at a cost of less than $4.00/ton and almost all at less than $6.00/ton. The outstanding exception to this is the Leland Olds plant in Stanton, North Dakota. Since there are no limestone quarries in the state, stone would have to be shipped a considerable distance. In this case, the source of limestone for which a price is given in the table is Rapid City, South Dakota, and transportation costs would be $10.80/ton.

The prices given in Table 22 are spot prices which do not take into account such factors as annual tonnages, number of shipments, etc. Negotiations between limestone producers, shippers, and power plant could produce some cost adjustments.

X. PROJECTED COSTS OF CARBONATE ROCKS

A. Base Price

Historically, prices of carbonate rocks have been very stable. They have increased at a much lower rate than the national economy or most commodities. For example, during the past 15 years, crushed limestone and dolomite have increased only 14% in average unit value. The abundance of rock deposits and the multiplicity of quarries have resulted in intense competition not only between limestone producers for the chemical and metallurgical markets, but also between limestone producers and producers of other types of rock for the large aggregate markets. As a result, prices have in general remained level or increased only slightly.

Figures 21-25 show the yearly variation in average unit value of all crushed stone, limestone and dolomite, marl, shell, and marble respectively. Unit values for 1960-1969 were calculated from data published in the corresponding year's Minerals Yearbook. Extrapolations to 1975 have been made in two ways: first, the data were extrapolated by following the trend and shape of the curve; second, a straight line extrapolation was made, using the average slope of the curve for the last few years. The former method represents an upper limit on the change in unit value which could normally be expected in the 6 year period. The latter method yields a more conservative estimate.

The curves shown in Figures 21 and 22 for crushed stone and for limestone and dolomite, follow the same general pattern, as expected. Prices remained essentially constant through 1966, after which a slight upward trend is noted. Extrapolation to 1975 gives a price range of about $1.75 - 2.00/ton for crushed stone, and, for limestone and dolomite, a range of $1.67 - 1.82/ton.

FIGURE 21

YEARLY VARIATION IN AVERAGE UNIT VALUE OF CRUSHED STONE

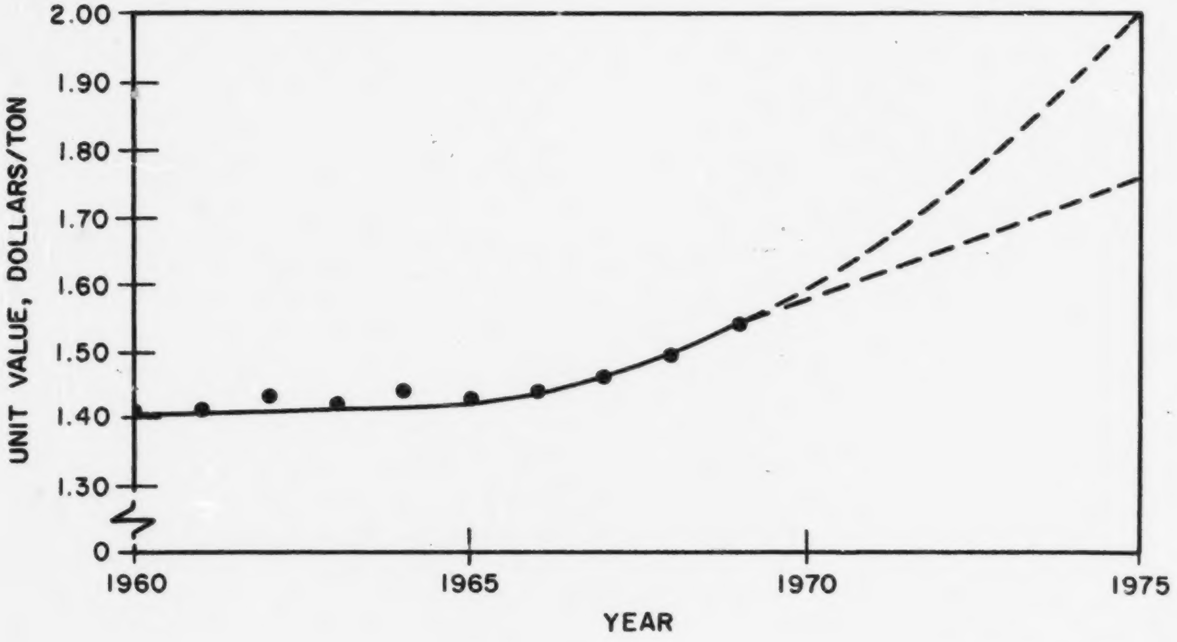


FIGURE 22

YEARLY VARIATION IN AVERAGE UNIT VALUE OF LIMESTONE AND DOLOMITE

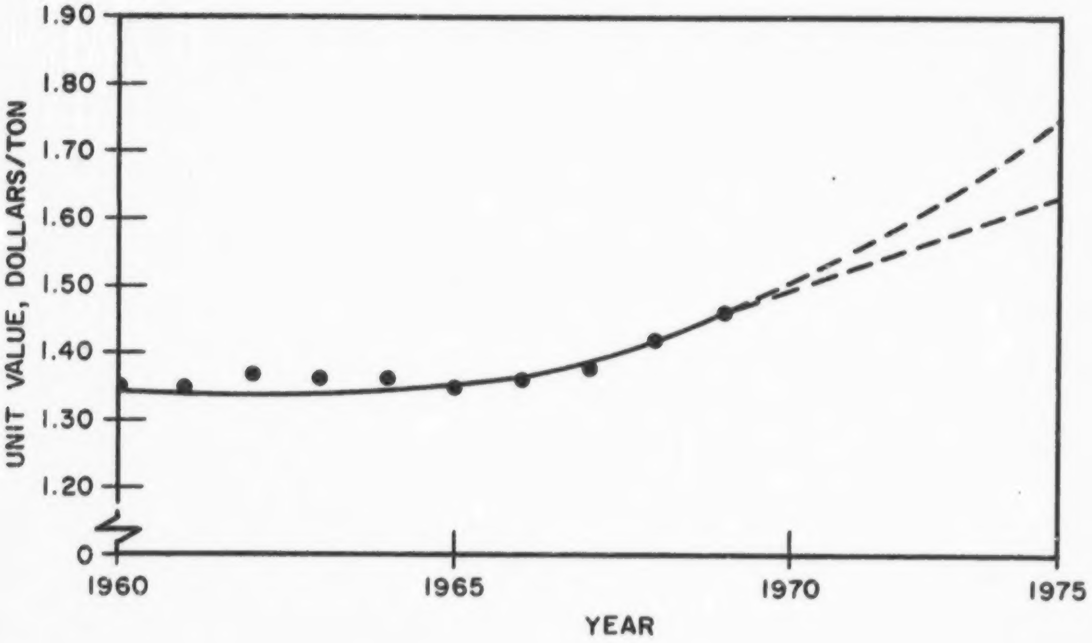


FIGURE 23

YEARLY VARIATION IN AVERAGE UNIT VALUE OF MARL

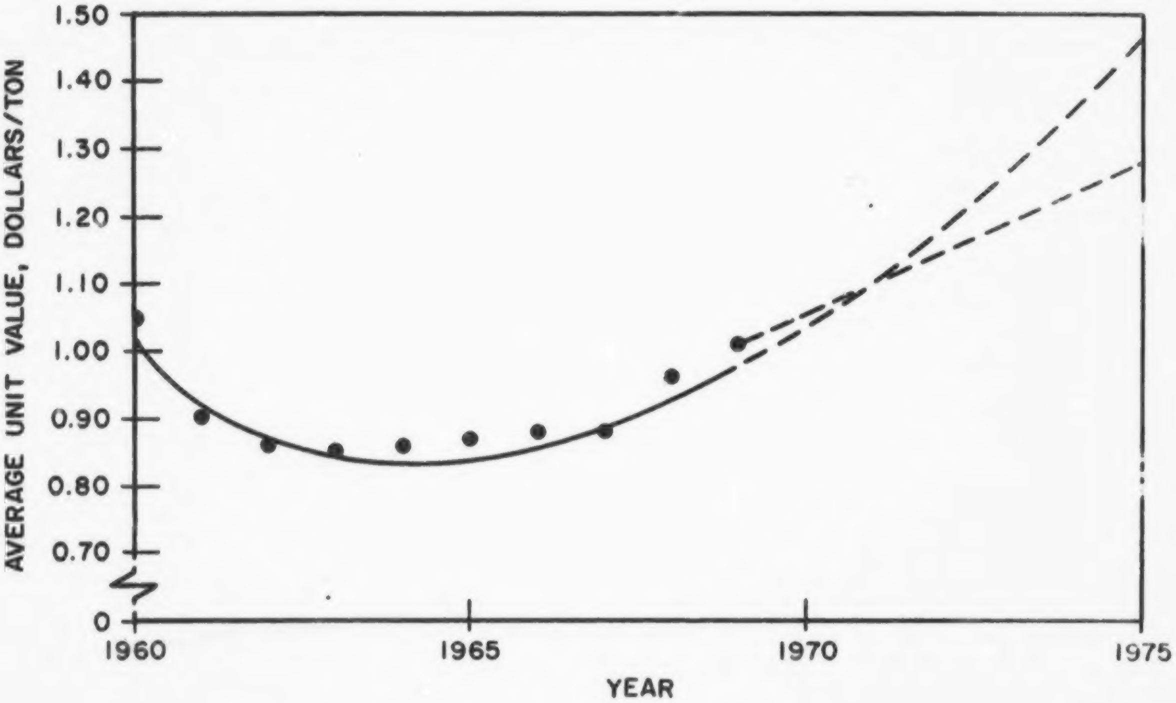


FIGURE 24
YEARLY VARIATION IN AVERAGE UNIT VALUE OF SHELL

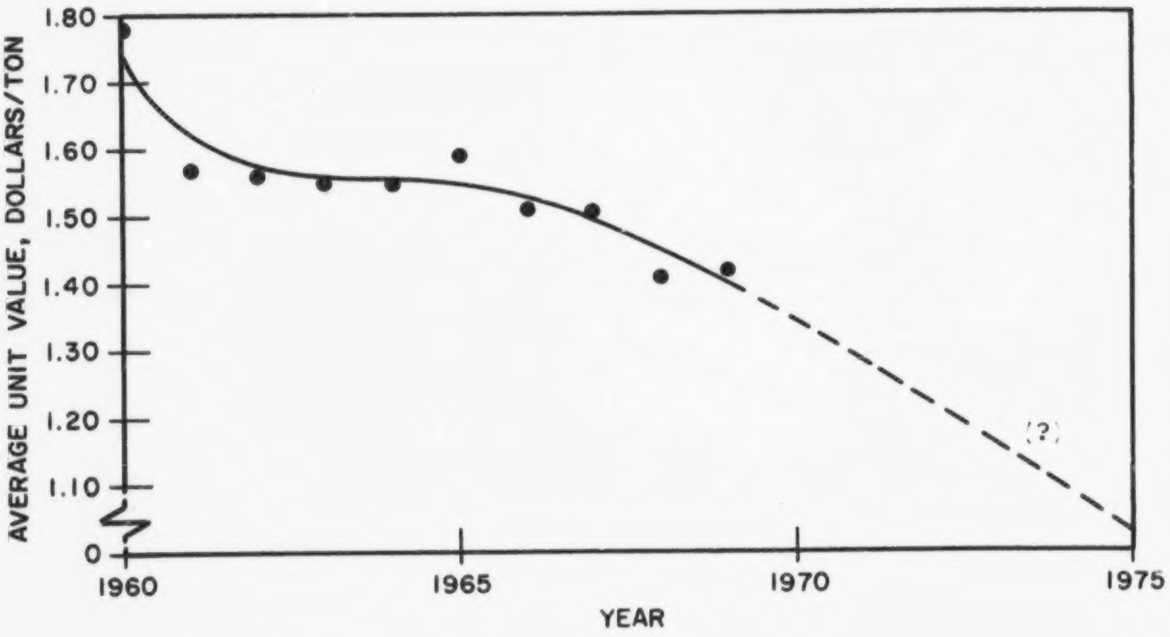
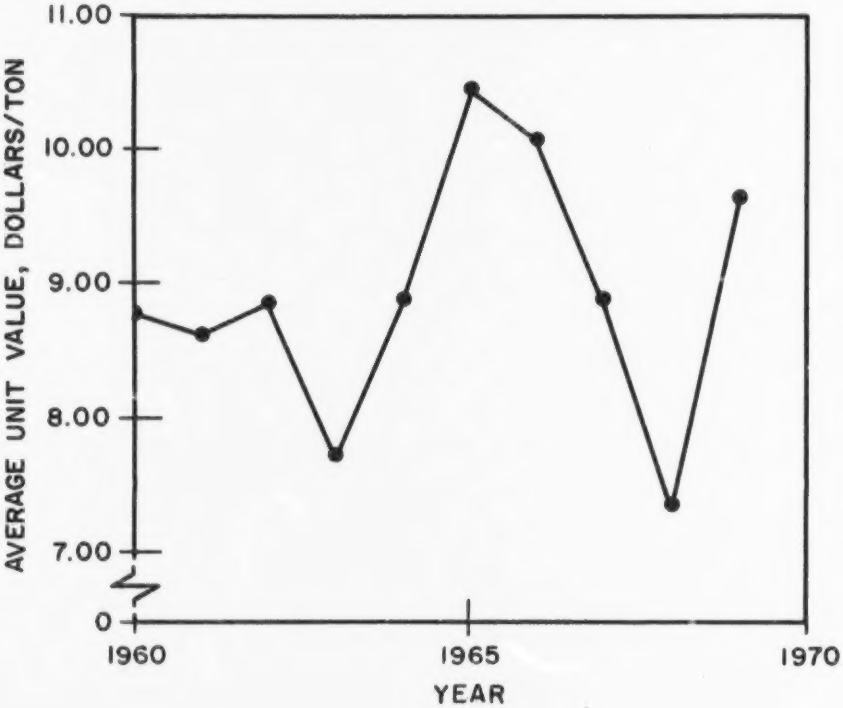


FIGURE 25
YEARLY VARIATION IN AVERAGE UNIT VALUE OF MARBLE



The latter corresponds to a modest average annual increase of 2.3 - 3.7%, based on the 1969 value.

The curve for marl, shown in Figure 23, has a slightly different shape. Prices decreased in the early 1960's, levelled out for a while, and have recently begun to increase. Projected values in 1975 are $1.28 - 1.48/ton, representing a 4.0 - 6.6% average annual increase.

Shell prices have dropped more than 20% over the 9-year period ending in 1969. Figure 24 shows that a sharp drop occurred in 1961 after which prices essentially remained steady through 1965. Prices since then have decreased. In this case, extrapolation of the curve appears to give unreasonable results, since the projected value of shell in 1975 is lower than that of marl, an unlikely situation. More probably, the price of shell will parallel that of limestone and dolomite, but should not exceed them in value.

Unit values for crushed marble are shown in Figure 25. The wide variation in values from year to year illustrates the high sensitivity of price to demand for crushed marble, and the special applications for which the material is used. No attempt was made to extrapolate the data because of the scatter of data points and because crushed marble, in order to be considered for use in a power plant, would have to have a much lower unit value than those shown in the figure.

B. Transportation Rates

Transportation rates are, in general, expected to rise at a higher rate than the average base price of limestone and dolomite in the next 5 years. Considering all methods of transportation, an average annual increase of about 6% is predicted, based on estimates by a number of stone and limestone producers.

Producers anticipate that truck rates will climb by 4-6%/year on the average. A few producers predict even higher rate increases, up to 20%/year. These latter predictions, however, should occur only in rare instances, and only under very special local conditions.

Increases in rail rates should average 6-8%/year during the 5 year period. Virtually all estimates by producers fall within a range of 3-8%/year. Some observers feel that, beyond 1971, drastic increases will occur in the south, bringing intrastate rates up to interstate levels.

Rates of water shipment of stone are expected to rise 5-10% annually. Increases as low as 2%/year and as high as 20%/year have been forecast, however. The high rate should only apply under unique circumstances.

Particularly for truck and rail transportation, rates should follow wage increases granted to labor. The estimates offered by stone producers are predicated on the present state of the economy and a continuance of the present inflation rate. Any changes will, of course, affect these estimates.

XI. SUPPLY/DEMAND RELATIONSHIP OF CARBONATE ROCKS FOR POLLUTION CONTROL

A. Proximity of Carbonate Rock Deposits to Power Plants

Figure 2, presented in Section VI C, shows the location of the major coal- and oil-fired power plants. Figures 4 through 7, presented in Section VII A, show the location of the major deposits of carbonate rocks, including limestone, dolomite, and marble. Comparison of these figures indicates that the major deposits largely coincide in location with the power plants.

This is particularly true in the East North Central region where huge reserves of stone occur. Both high calcium limestone and high grade dolomite abound, and many deposits are found near the major power generation centers throughout the region.

The New England region is not as fortunate. While the power plants are located primarily in coastal areas, the rock deposits occur in the mountainous western sections. Most of the deposits are highly crystalline stone or marble, and many are dolomitic. If final process specifications indicate the desirability of using, for example, a non-crystalline high calcium stone, then even these materials would be excluded from consideration.

Availability of stone should not be a problem for power plants in the Middle Atlantic region. All types of stone occur and nearby deposits can be found. Plants in western and eastern Pennsylvania, particuarly, are fortunate in that large reserves of high grade stones are present.

In the South Atlantic region, most plants are located near an adequate source of stone, particularly if the crystalline limestones and dolomites of the mountainous areas prove suitable.

Several coastal plants could use shell or coral limestone, or marl. However, for some inland power plants in, for example, North Carolina, no nearby deposits exist.

Large quantities of high calcium limestone occur throughout the East South Central region and power plants should experience no difficulty in obtaining adequate supplies. Should dolomite prove feasible for SO_x removal, plants located in Alabama and Tennessee also could obtain this material.

The less abundant and more widely scattered carbonate resources of the western states are of minor importance, since there are few coal-fired power plants in this area. With the exception of the two power plants located in North Dakota, which are far removed from any commercially important carbonate deposits, the few plants that do exist are fairly near reserves of high calcium stone.

It is very difficult to determine quantitatively the usable reserves of stone within a given region or area, and relate this to potential consumption by power plants in the area. However, to give an overall view of the extent of usable reserves, a comparison can be made between estimated reserves and rock production rates. This is shown in Table 23.

The area of surface reserves was estimated using Figure 4. For various assumed overall average thicknesses, this area was converted to an equivalent amount of carbonate rock, based on the assumptions listed in the table. The estimated reserve was then compared to the 1969 production rate for all carbonate rocks.

TABLE 23

RELATIVE SUPPLY OF SURFACE CARBONATE ROCKS IN THE UNITED STATES

Area of Surface Reserves = 316,000 Sq. Mi.(1)

Assumed Average Thickness Of Deposits (Ft.)	Equiv. Reserves(2) (10^{12} Tons)	Years Supply At 1969 Production Rate(3)
1	0.363	557
10	3.63	5,570
25	9.08	13,900
50	18.2	27,900
100	36.3	55,700

---

(1) Estimated from Figure 4

(2) Based on the following assumptions:

(a) Figure 4 shows areas in which the predominant rock type at the surface is carbonate. Hence, it was assumed that these areas contain a minimum of 50% carbonate rock. Therefore, the areal extent of surface carbonate rocks is at least 0.5 x 316,000 sq.mi., or 158,000 sq.mi.

(b) Average density of carbonate rock = 165 lb./cu.ft.

(3) Total carbonate rock production in 1969 was 652 MM tons

As shown, even for an assumed average thickness of only one foot, the total surface reserves would be sufficient for over 500 years of production. If it were further assumed that only 10% of the reserves were usable, they could still supply stone for almost 60 years. On the assumption of an average thickness of 10 feet (a reasonable, and probably conservative value), it can be seen that overall reserves are more than adequate to provide stone for even long term needs.

The estimates shown in Table 23 should be regarded as approximations only, since several factors were neglected. Among these were deposits interbedded with, or under, other rock types, the nature and composition of the deposits, etc.

B. Potential Demand Relative to Production

As mentioned in Section VI-D, the potential demand for limestone by coal- and oil-fired power plants in 1969 was about 41 million tons. This represents only 7.3% of the national limestone production of 559 million tons. Dolomite production was roughly 50% greater than the potential demand while shell production was only one-half of the demand. The quantities of calcareous marl and crushed marble quarried were relatively insignificant. Obviously, limestone is the only stone produced in sufficient quantities to warrant nationwide consideration as an agent for SO_x removal. Dolomite and shell, however, are quarried in large enough amounts to make them important materials in some regions. Marl and crushed marble may be useful in certain localities where the other rocks do not exist, but their limited occurrence and production do not permit wide-scale use of these materials.

In Table 24, an attempt was made to relate 1969 limestone and dolomite production to potential demand by power plants. Production rates were taken from Table 19 and values for potential demand were taken from Figure 3. The ratio of production to potential demand is defined as the PPD ratio and indicates the relative supply of limestone and dolomite. The use of the data in this manner ignores, of course, the purity of the stone produced, the difference in reactivity and capacity between calcium carbonate and magnesium carbonate, and other factors. However, no information on average composition of stones produced in each state is available. With these limitations in mind, the figures for PPD ratio should give an approximate picture of the supply/demand relationship throughout the country.

With the exception of New England, the eastern regions of the country all have large relative supplies of limestone and dolomite. There are, though, some exceptions to this among the individual states. New Jersey and Delaware have a potential need which exceeds their production. Adjacent states, however, are large producers of stone and could provide the necessary tonnages. Mississippi and both of the Carolinas have low relative supplies of stone. If they could not otherwise be supplied, marl deposits, which occur extensively in all three states, could be used. Georgia and West Virginia, with comparatively low relative supplies, could easily obtain needed stone from surrounding states. It is interesting to note that the region with the highest potential limestone demand, i.e., the East North Central region, also has the highest limestone and dolomite production.

TABLE 24

PRODUCTION/POTENTIAL DEMAND RELATIONSHIP OF LIMESTONE AND DOLOMITE FOR POLLUTION CONTROL (1969)

Region and State	Production[(1)] (M Tons)	Potential Demand[(2)] (M Tons)	PPD Ratio[(3)]
New England			
Connecticut	(275)[(4)]	487	0.56
Maine	(800)	61	13.1
Massachusetts	(750)	636	1.18
New Hampshire	-	141	0
Rhode Island	(<100)	39	<2.56
Vermont	(525)	5	105
Totals	(2,400)	1,369	1.75
Middle Atlantic			
New Jersey	(800)	935	0.86
New York	33,457	2,132	15.7
Pennsylvania	56,667	3,516	16.1
Totals	(90,900)	6,583	13.8
South Atlantic			
Delaware	-	177	0
Florida	40,729	1,009	40.4
Georgia	4,334	931	4.66
Maryland	9,804	1,010	9.71
North Carolina	(4,500)	2,003	2.25
South Carolina	(1,900)	459	4.14
Virginia	17,829	1,088	16.4
West Virginia	8,405	1,794	4.69
Totals	(87,500)	8,471	10.3
East South Central			
Alabama	17,752	1,931	9.19
Kentucky	30,158	1,785	16.9
Mississippi	(300)	71	4.23
Tennessee	33,109	1,858	17.8
Totals	(81,300)	5,645	14.4
East North Central			
Illinois	54,844	3,665	15.0
Indiana	25,157	2,786	9.03
Michigan	39,066	2,511	15.6
Ohio	50,595	4,181	12.1
Wisconsin	15,937	1,164	13.7
Totals	185,600	14,307	13.0
West North Central			
Iowa	(26,200)	453	57.8
Kansas	15,334	42	365
Minnesota	4,127	648	6.37
Missouri	41,200	1,093	37.7
Nebraska	4,663	110	42.4
North Dakota	-	357	0
South Dakota	989	35	28.3
Totals	(92,500)	2,738	33.8

TABLE 24 (Cont'd

PRODUCTION/POTENTIAL DEMAND RELATIONSHIP OF LIMESTONE AND DOLOMITE FOR POLLUTION CONTROL (1969)

Region and State	Production[1] (M Tons)	Potential Demand[2] (M Tons)	PPD Ratio[3]
West South Central			
Arkansas	5,676	4	1419
Louisiana	-	<1	0
Oklahoma	(16,300)	<1	Large
Texas	(36,300)	<1	Large
Totals	(58,300)	<7	Large
Mountain			
Arizona	2,339	50	46.8
Colorado	(1,650)	358	4.61
Idaho	(250)	-	∞
Montana	(1,442)	74	19.5
Nevada	(1,000)	78	12.8
New Mexico	956	345	2.77
Utah	(2,400)	67	35.8
Wyoming	649	379	1.71
Totals	(10,700)	1,351	7.92
Pacific			
California	(17,400)	266	65.4
Oregon	(350)	<1	Large
Washington	(1,050)	<1	Large
Totals	(18,800)	<268	>70

---

(1) taken from Table 19

(2) taken from Figure 3

(3) PPD Ratio $\equiv \frac{\text{Production of Limestone and Dolomite}}{\text{Potential Demand by Power Plants}}$

(4) ( ) indicates that production figure was estimated.

The New England region faces a shortage of limestone and dolomite, with two states producing less stone than potentially required. The marble resources of the region could improve the situation somewhat, but power plants would have to rely on shipments of stone from other states such as New York, or, perhaps, on imports.

Most states in other regions of the country have ample limestone production. North Dakota, having no production, is an exception to this. A few other states also have low relative supplies of limestone, but either the demand is quite small, or the production could easily be expanded to meet the need.

Long range availability of limestone in the United States may be a problem if a metallurgical grade stone is required for SO_x removal. One authority(1) estimates that only 2 of the known deposits will still be producing metallurgical grade stone 40 years from now. However, it is likely that the stone purity required for power plant use will be dictated largely by reactivity, cost, and other factors. If this is the case, the vast reserves of carbonate rocks should last for the foreseeable future.

C. Some Factors Which Could Affect Availability and Cost of Limestone

The limestone industry is a very competitive one which produces a low cost, low profit commodity. Because of its low value, and the abundance of quarries, limestone cannot stand high transportation costs, and is generally not shipped for long distances. Most consumers purchase stone from nearby quarries. Wide-scale use of limestone for pollution control could have a significant local effect on the limestone industry, particularly where several quarries could supply a suitable stone.

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(1) Landes, Kenneth K., Metallurgical Limestone Reserves in the United States, 2nd ed., National Lime Association, Washington, D.C., p. 1 (1963)

Although final process specifications as to particle size have not yet been determined, it is likely that a fine material, e.g., 325 mesh, will be required. For various reasons, grinding to this size probably will be done at the power plant. Consequently, a power plant could seek the lowest cost stone, regardless of size.

In the course of producing crushed limestone, many quarries also produce a reject material consisting of fines from the screening operations. This material is sometimes marketed as a byproduct, possibly after further grinding, but commonly it is stored in waste piles. This could be an economical source of stone for a power plant, while at the same time affording the quarry operator an outlet for an otherwise valueless material. The long-term availability would, of course, depend on the relative production and depletion rates of the material.

The same situation might also occur where a power plant is located near a quarry producing dimension limestone or marble. Waste material resulting from the drilling, blasting, and cutting of the stone could be an ideal source of low-cost limestone.

Since a major use of limestone is in road construction, many quarries experience a variable demand. As roads progress further from the quarry site, economics begin to favor purchase of stone from another quarry closer to the construction area. In northern climates, there is also a seasonal demand, since road construction halts during the winter months. The predictable and constant demand by a power plant could have a stabilizing effect on the quarry operation, resulting in a lower cost stone for the power plant.

The limestone requirements of a power plant could justify the expansion of quarry operations in some instances. In areas where deposits exist but no production occurs, a power plant's needs possibly could result in a completely new quarry operation. Though not likely, it is conceivable that a utility might even operate its own quarry in unique situations.

XII. PHYSICAL PROPERTIES

Physical properties, particularly those which affect a stone's suitability for use in road construction, have been published for many limestones, dolomites, and marbles in the United States; few properties, however, have been reported for shell or marl. The physical properties vary widely, depending upon chemical composition, crystal structure, and the nature of the impurities contained in the stone.

Values of some physical properties for selected stones are given, by region and state, in Tables 25-33. In each table, the stones are identified by numbers which correspond to those on the regional maps in Figures 26-34.

A. Specific Gravity

The true specific gravity of pure calcite at room temperature is 2.71. Aragonite, the orthorhomic form of calcium carbonate, and dolomite have somewhat higher values, near 2.94 and 2.8 - 2.9, respectively. Impurities have but a small effect on the true specific gravity.

B. Bulk Density

Bulk density, as used here, refers to the weight per unit volume of rock, including internal pores but excluding interparticle voids, i.e., particle density. Bulk density of carbonate rocks vary widely, but the following ranges are typical of most stones:

	lb/ft^3
Limestone	155-175
Dolomite	160-180
Marble	165-180

TABLE 25

TYPICAL PROPERTIES OF CARBONATE ROCKS

NEW ENGLAND REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Deval)	Hardness	Toughness
Connecticut					
	1	2.85	5.5	11.3	7
	2	2.75	5.7	15.2	6
Maine					
	1	2.70	5.6	10.5	5
Massachusetts					
	1	2.87	7.2	11.2	2
	2	2.80	5.4	18.2	21
Rhode Island	1	2.37	8.8	11.3	5
Vermont					
	1	2.80	3.2	17.3	22
	2	2.74	3.0	17.3	9
	3	2.69	7.2	11.0	2

(1) Sample numbers correspond to those shown on Figure 26

(2) See text for explanation of properties

TABLE 26

TYPICAL PROPERTIES OF CARBONATE ROCKS

MIDDLE ATLANTIC REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Deval)	Hardness	Toughness
New Jersey	1	2.82	2.9	16.0	20
	2	2.85	3.5	17.1	14
New York	1	2.64	4.8	18.7	24
	2	2.69	4.8	16.1	10
	3	2.75	3.1	14.8	6
Pennsylvania	1	2.65	5.9	16.7	12
	2	2.75	6.2	15.0	8
	3	2.80	6.9	16.7	20

(1) Sample numbers correspond to those shown on Figure 27.

(2) See text for explanation of properties.

TABLE 27

TYPICAL PROPERTIES OF CARBONATE ROCKS

EAST NORTH CENTRAL REGION

State	Sample No.(1)	Bulk Specific(2) Gravity	Abrasive Loss (Deval)	Hardness	Toughness
Illinois	1	2.60	9.1	14.2	6
	2	2.60	4.9	18.1	6
	3	2.67	5.9	12.7	4
Indiana	1	2.75	8.7	16.2	21
	2	2.65	3.9	13.9	8
	3	2.30	8.6	1.8	4
Michigan	1	2.75	4.2	14.3	6
	2	2.60	4.5	12.5	9
	3	2.70	9.5	8.3	5
Ohio	1	2.65	8.0	6.8	5
	2	2.60	4.2	18.3	13
	3	2.70	6.2	9.3	4
Wisconsin	1	2.85	3.8	12.8	6
	2	2.65	3.9	14.5	11
	3	2.70	6.7	13.3	9

(1) Sample numbers correspond to those on Figure 28

(2) See text for explanation of properties

TABLE 28

TYPICAL PROPERTIES OF CARBONATE ROCKS

WEST NORTH CENTRAL REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Deval)	Hardness	Toughness
Iowa					
	1	2.70	6.0	13.0	2
	2	2.75	14.6	13.6	6
	3	2.65	4.6	15.6	8
Kansas					
	1	2.71	4.2	15.3	10
	2	2.45	9.0	11.7	3
	3	2.70	9.0	12.8	4
Minnesota					
	1	2.55	4.7	16.8	14
	2	2.58	7.2	14.0	8
	3	2.70	5.0	13.3	5
Missouri					
	1	2.65	5.3	12.0	2
	2	2.70	3.4	16.6	14
	3	2.80	4.0	15.5	10
Nebraska					
	1	2.62	6.2	12.0	3
	2	2.45	5.1	11.0	7
South Dakota					
	1	2.71	6.6	14.3	4
	2	2.31	14.2	6.7	6

(1) Sample numbers correspond to those shown on Figure 29.

(2) See text for explanation of properties.

TABLE 29

TYPICAL PROPERTIES OF CARBONATE ROCKS

SOUTH ATLANTIC REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Devol)	Hardness	Toughness
Delaware					
	1	2.85	4.2	14.3	6
Florida					
	1	2.34	18.5	9.7	6
	2	2.48	7.5	14.9	2
	3	2.45	10.4	-	-
Georgia					
	1	2.70	5.3	14.7	5
	2	2.85	4.1	9.6	5
	3	2.00	22.2	19.3	5
Maryland					
	1	2.70	4.0	16.5	12
	2	2.71	2.5	17.7	17
	3	2.85	18.8	4.5	2
North Carolina					
	1	2.74	5.0	15.0	5
	2	2.24	33.6	17.6	5
	3	2.44	9.8	12.7	5
South Carolina					
	1	2.75	5.7	8.7	8
Virginia	1	2.85	3.6	15.0	9
	2	2.78	3.3	17.3	23
	3	2.75	4.6	15.7	4
West Virginia					
	1	2.70	3.3	16.8	11
	2	2.75	3.5	16.5	16
	3	2.65	2.3	18.8	23

(1) Sample numbers correspond to those shown on Figure 30.

(2) See text for explanation of properties.

TABLE 30

TYPICAL PROPERTIES OF CARBONATE ROCKS

EAST SOUTH CENTRAL REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Devol)	Hardness	Toughness
Alabama					
	1	2.42	5.1	18.0	29
	2	2.80	5.0	16.0	8
	3	2.65	7.8	15.0	7
Kentucky					
	1	2.70	5.1	14.1	12
	2	2.68	4.9	14.0	6
	3	2.71	3.2	13.7	8
Mississippi					
	1	2.40	12.2	6.7	5
	2	2.50	5.6	12.0	5
	3	2.60	-	10.7	5
Tennessee					
	1	2.70	4.4	15.6	6
	2	2.75	5.1	15.5	4
	3	2.71	6.0	13.3	2

(1) Sample numbers correspond to those shown on Figure 31.

(2) See text for explanation of properties.

TABLE 31

TYPICAL PROPERTIES OF CARBONATE ROCKS

WEST SOUTH CENTRAL REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss	Hardness	Toughness
Arkansas					
	1	2.69	5.4	15.3	7
	2	2.68	10.5	7.3	3
	3	2.65	13.9		
Louisiana					
	1	2.65	4.7	12.1	10
	2	2.65	10.4	9.0	3
Oklahoma					
	1	2.64	4.1	16.2	7
	2	2.55	8.2	11.0	5
	3	2.62	5.9	15.3	8
Texas					
	1	2.58	7.2	12.0	7
	2	2.33	7.8	5.7	3
	3	2.65	4.8	13.2	6

(1) Sample numbers correspond to those shown on Figure 32.

(2) See text for explanation of properties.

TABLE 32

TYPICAL PROPERTIES OF CARBONATE ROCKS

MOUNTAIN REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Deval)	Hardness	Toughness
Arizona					
	1	2.47	12.1	15.7	6
	2	2.55	5.2	15.3	6
	3	2.70	6.8	10.7	4
Colorado					
	1	2.70	4.6	13.3	6
	2	2.60	4.5	-	-
	3	2.45	7.3	3.0	6
Montana					
	1	2.65	7.5	12.9	5
	2	2.62	3.4	17.0	14
New Mexico	1	2.71	6.2	16.7	8
	2	2.67	4.6	16.7	8
	3	2.40	-	17.0	4
Utah					
	1	2.70	2.9	16.8	12
	2	2.31	7.3	12.0	3
Wyoming					
	1	2.60	6.4	15.3	4

(1) Sample numbers correspond to those shown on Figure 33.

(2) See text for explanation of properties.

TABLE 33

TYPICAL PROPERTIES OF CARBONATE ROCKS

PACIFIC REGION

State	Sample No.(1)	Bulk Specific Gravity(2)	Abrasive Loss (Deval)	Hardness	Toughness
California					
	1	2.70	2.3	16.7	8
	2	-	3.3	15.9	12
	3	2.70	4.4	14.4	4
Oregon					
	1	2.65	5.9	16.7	7
Washington					
	1	2.75	2.8	18.0	19
	2	2.75	4.8	12.0	5
	3	2.80	5.6	17.1	7

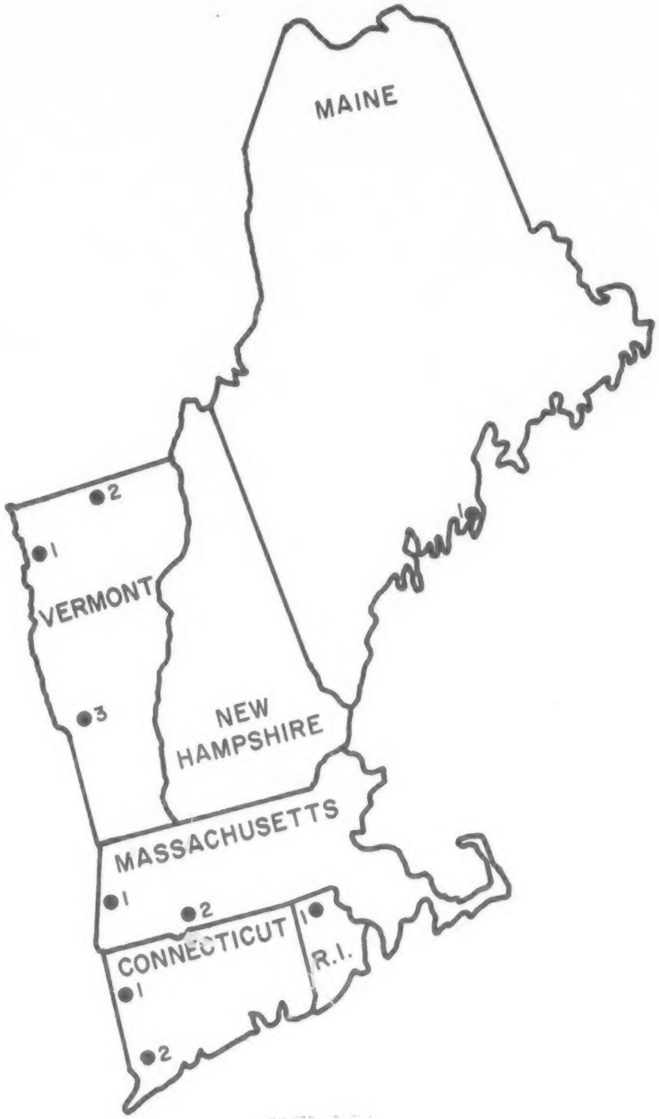
(1) Sample numbers correspond to those shown on Figure 34.

(2) See text for explanation of properties.

FIGURE 26

LOCATION OF CARBONATE ROCK SAMPLES

NEW ENGLAND REGION

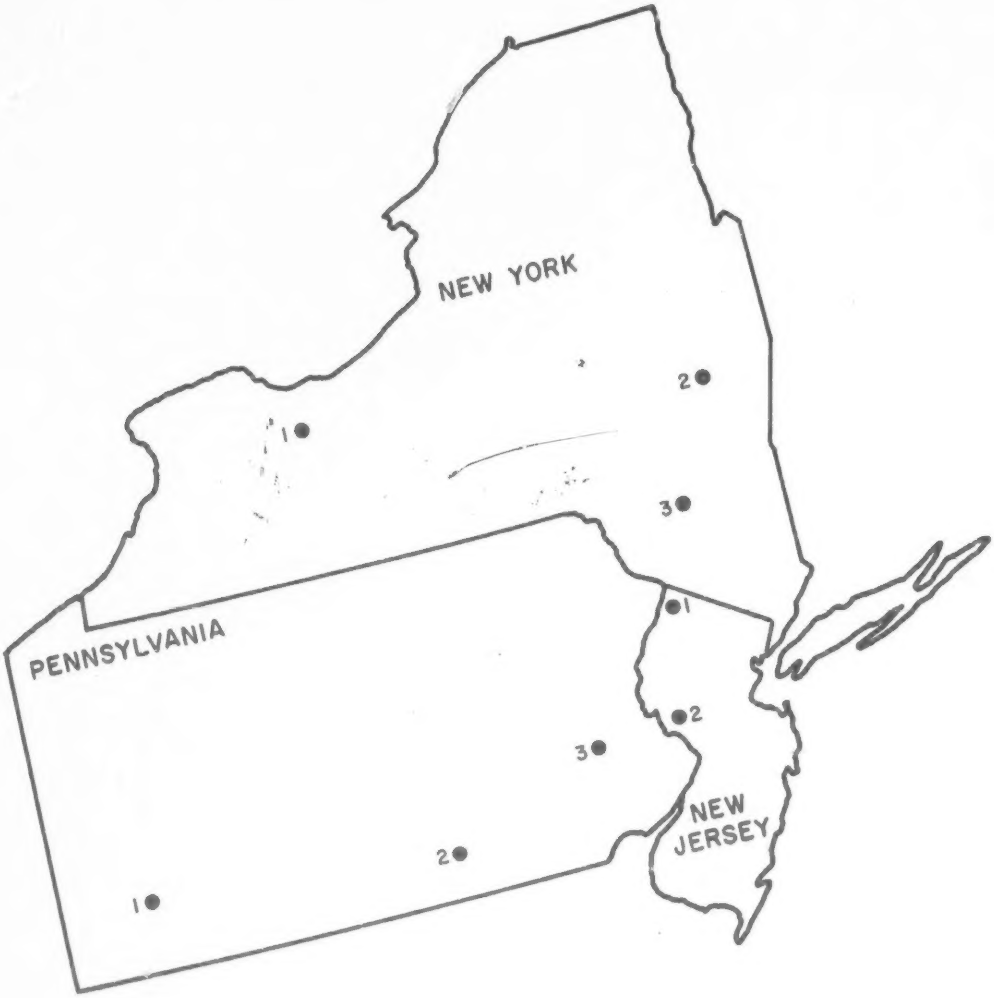

MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
R.I.
2
1
3
1
2
1
1
2

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 25)

FIGURE 27

LOCATION OF CARBONATE ROCK SAMPLES

MIDDLE ATLANTIC REGION

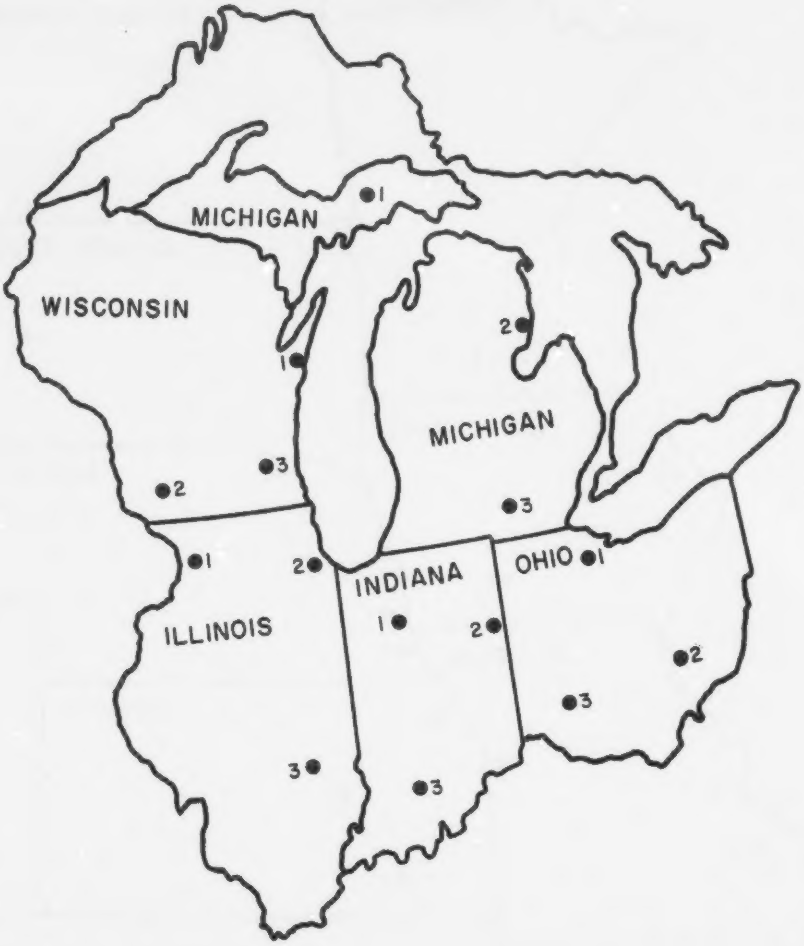

NEW YORK
2
1
3
PENNSYLVANIA
1
2
3
NEW JERSEY
1
2
3
1
2

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 26)

FIGURE 28

LOCATION OF CARBONATE ROCK SAMPLES

EAST NORTH CENTRAL REGION

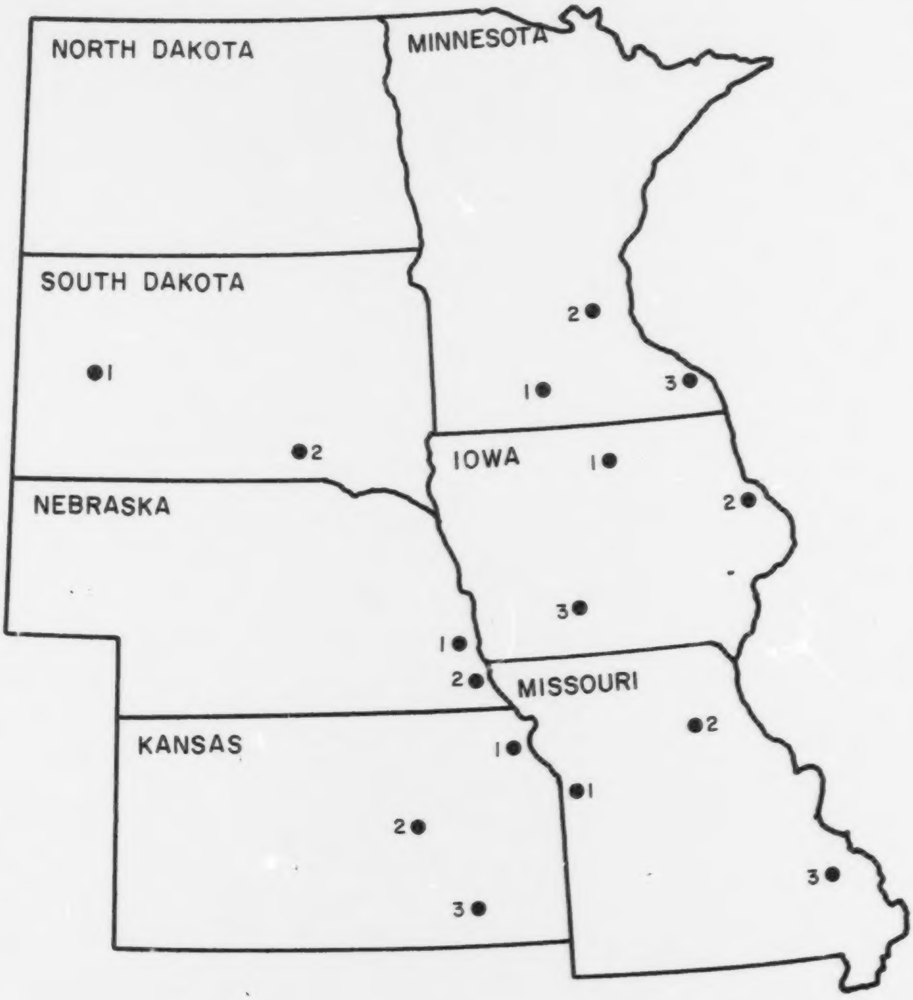

MICHIGAN
1
WISCONSIN
1
2
3
2
MICHIGAN
3
1
2
ILLINOIS
3
INDIANA
1
2
3
OHIO
1
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 27)

FIGURE 29

LOCATION OF CARBONATE ROCK SAMPLES

WEST NORTH CENTRAL REGION

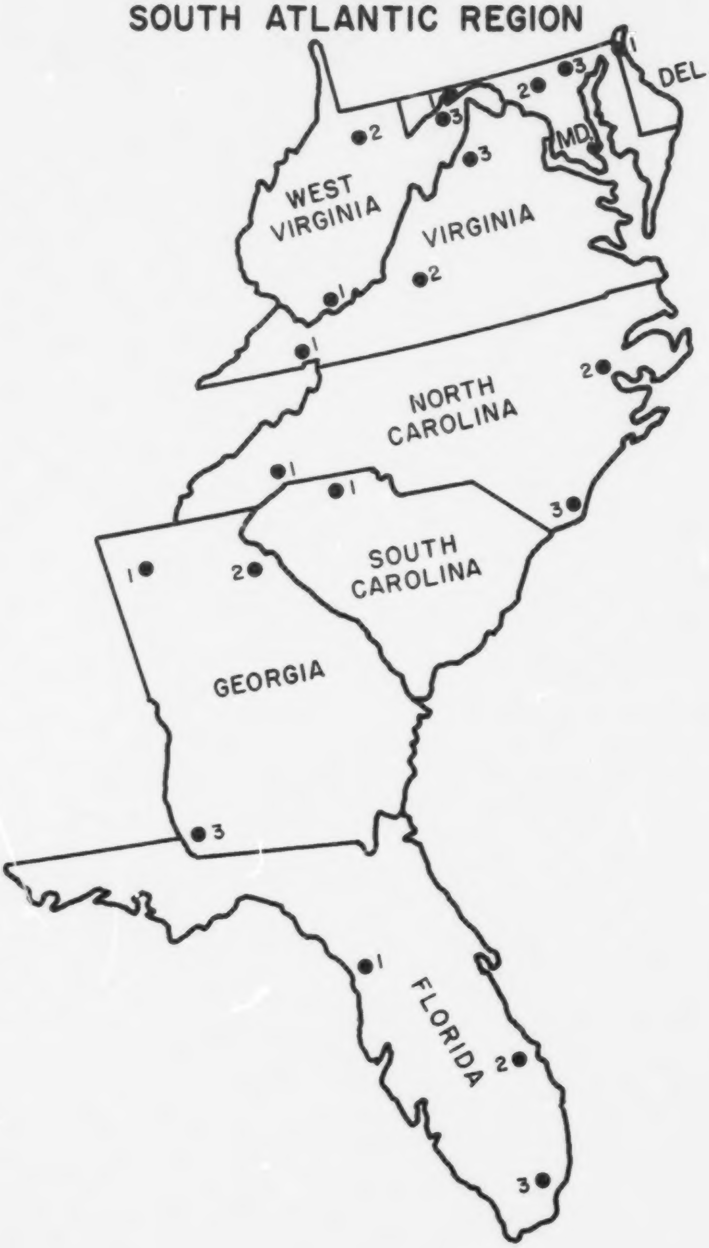

NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IOWA
NEBRASKA
MISSOURI
KANSAS
1
2
3
1
2
1
2
3
1
2
1
2
3
1
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 28)

FIGURE 30

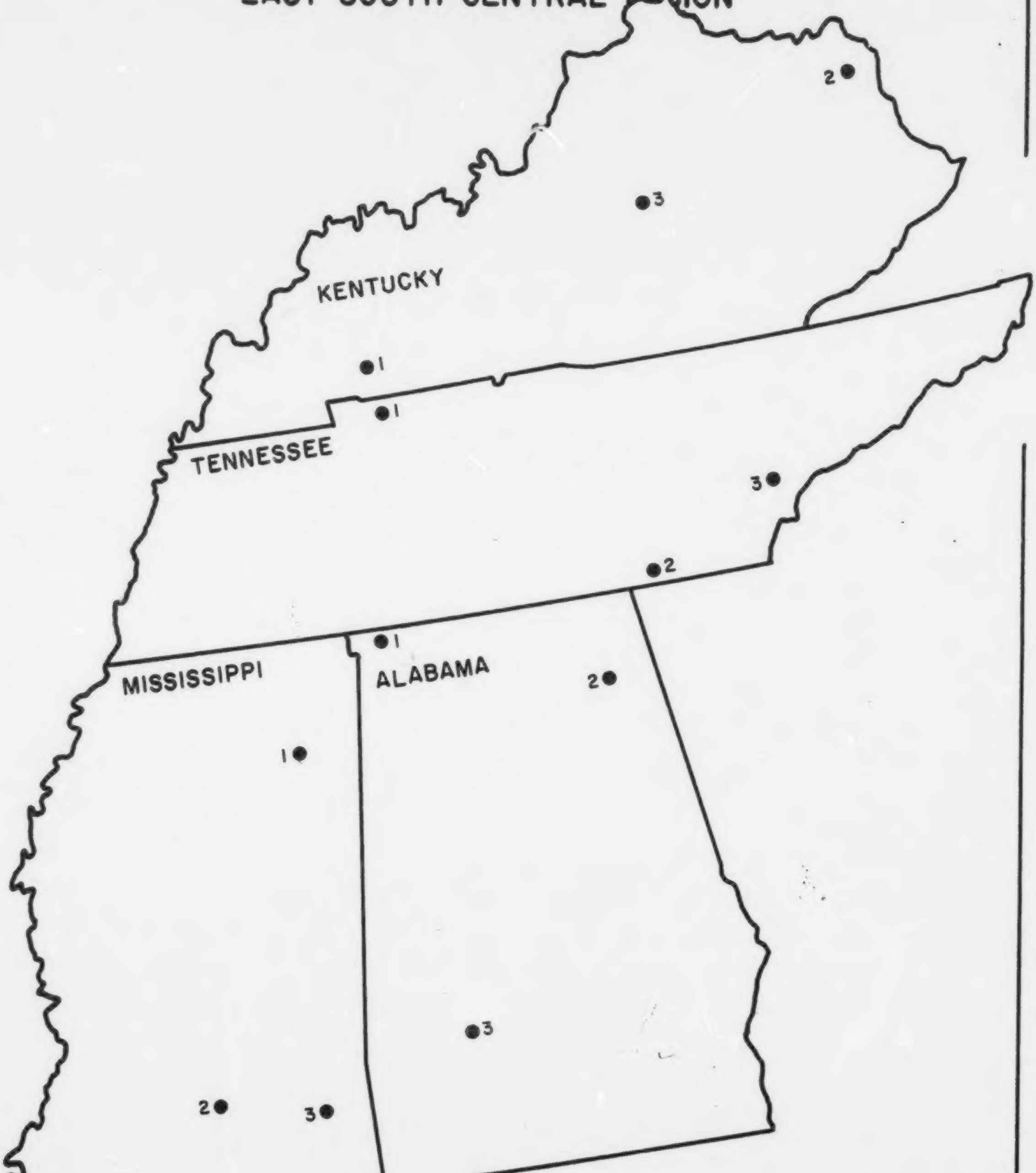
LOCATION OF CARBONATE ROCK SAMPLES

SOUTH ATLANTIC REGION


DEL.
MD.
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
1
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 29)

FIGURE 31
LOCATION OF CARBONATE ROCK SAMPLES
EAST SOUTH CENTRAL REGION

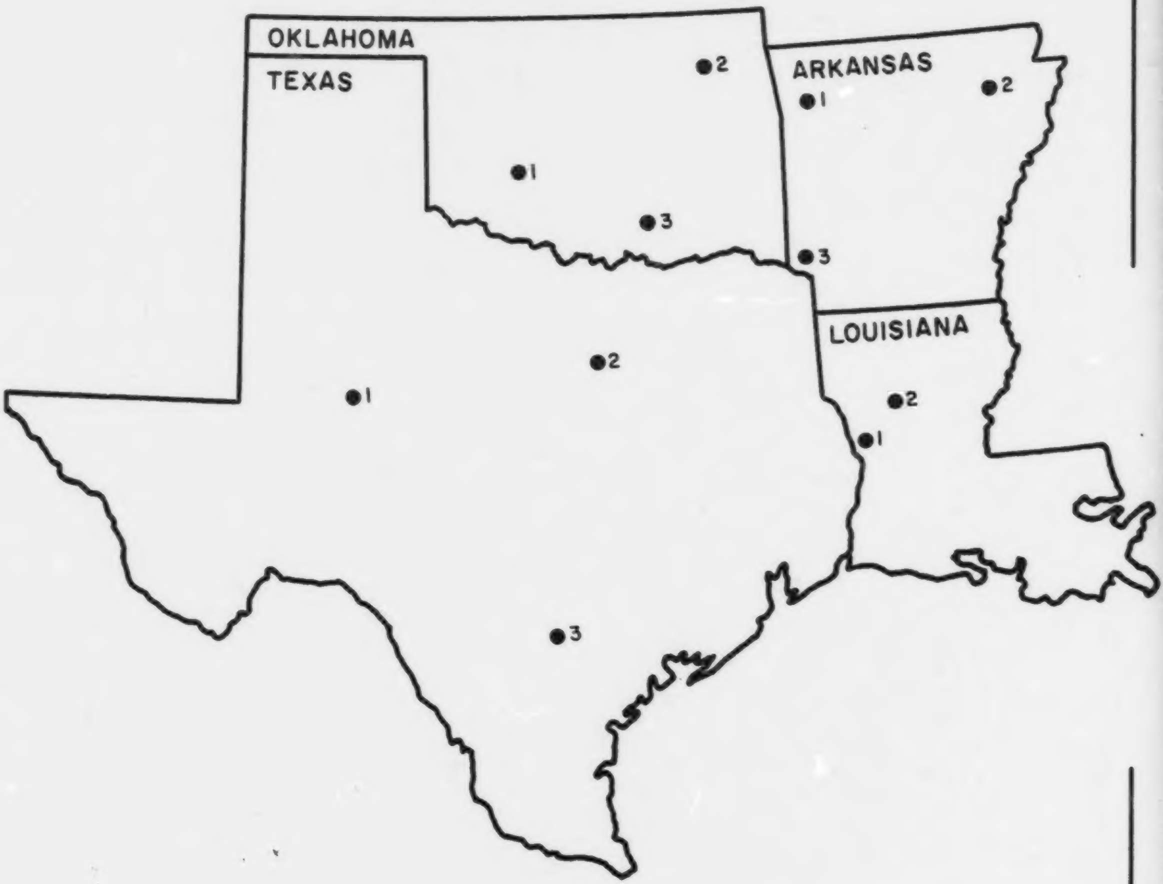

KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
2
3
1
1
3
2
1
2
1
3
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 30)

FIGURE 32

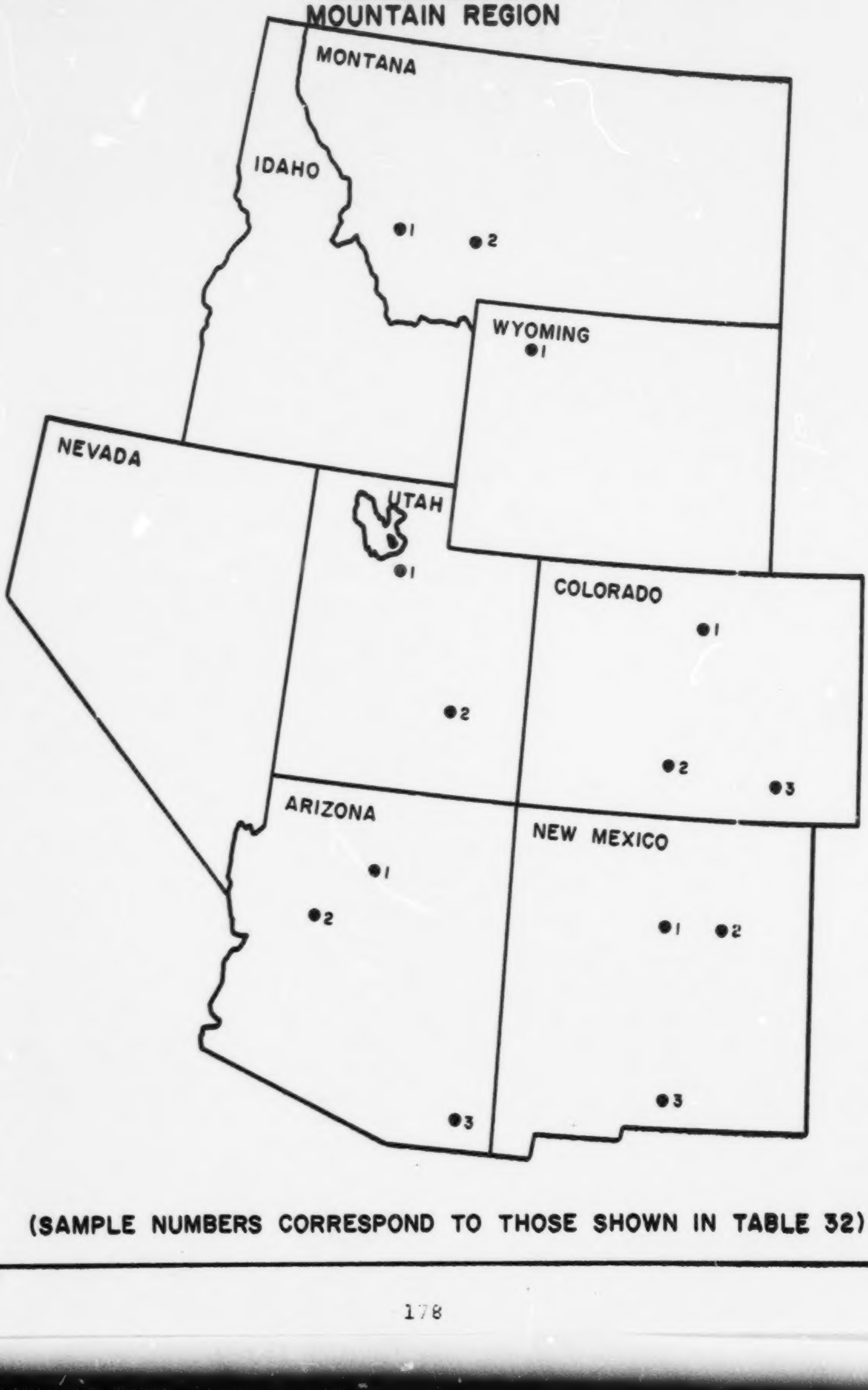
LOCATION OF CARBONATE ROCK SAMPLES

WEST SOUTH CENTRAL REGION


OKLAHOMA
TEXAS
ARKANSAS
LOUISIANA
●2
●1
●3
●1
●2
●3
●1
●2
●3
●2
●1

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 31)

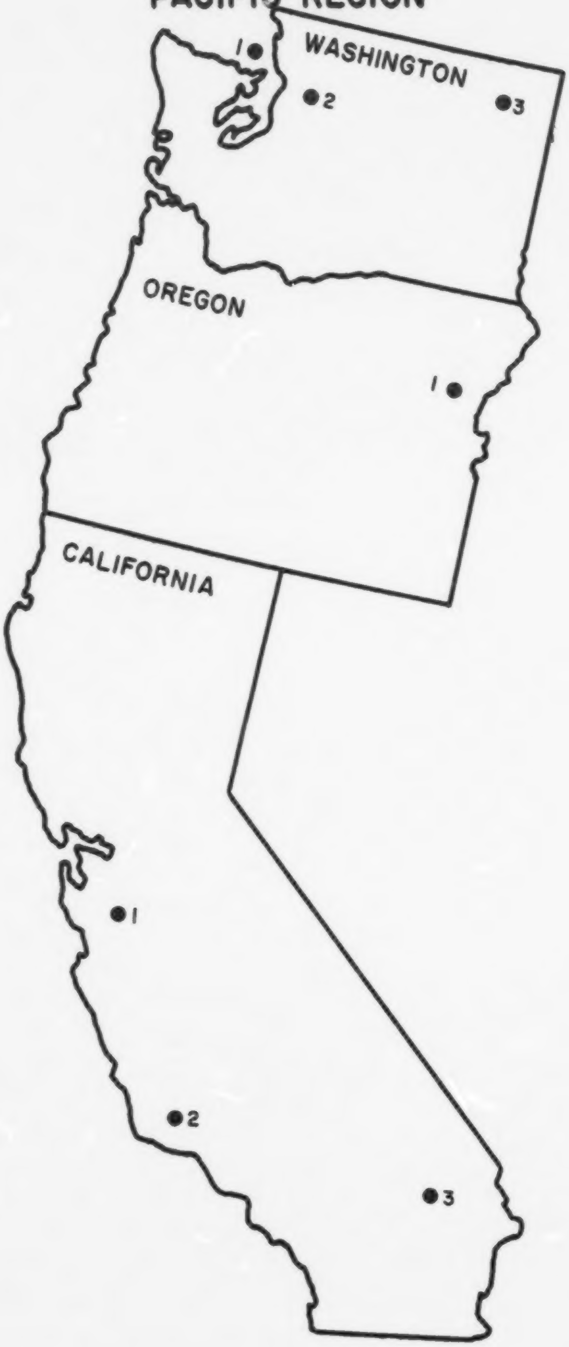
FIGURE 33
LOCATION OF CARBONATE ROCK SAMPLES
MOUNTAIN REGION


MONTANA
IDAHO
1
2
WYOMING
1
NEVADA
UTAH
1
2
COLORADO
1
2
3
ARIZONA
1
2
3
NEW MEXICO
1
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 32)

FIGURE 34
LOCATION OF CARBONATE ROCK SAMPLES

PACIFIC REGION


WASHINGTON
1
2
3
OREGON
1
CALIFORNIA
1
2
3

(SAMPLE NUMBERS CORRESPOND TO THOSE SHOWN IN TABLE 33)

Chalk, a very porous material, has a much lower bulk density. A typical range would be 100 - 125 lb/ft^3, although even lower values have been reported.

C. Porosity

Porosity, as determined by water absorption tests, has been reported for many carbonate rocks. The test procedure consists of immersing a rock sample, usually 2 inches or less in diameter, in water for 24 hours after which it is surface dried and weighed. Porosity, i.e., the pore volume expressed as a percentage of the total volume of the rock, can be calculated from the weight of water absorbed and the density of the rock.

Values of porosity of up to 15% have been reported for limestones and dolomites, but most stones fall within the range of 0.3 - 6.0%. Values for marble are generally less than 1.0%, with many marbles having porosities of 0.1% or lower. The porosity of chalk varies considerably, with values as high as 50% reported. A typical range would be 10 - 40%.

D. Abrasive Loss

Abrasion tests historically have been used to determine the suitability of a stone for use as a road aggregate material. Results from these tests, in addition to other properties such as hardness, toughness, and crushing strength, which are mentioned later, can give a qualitative measure of the grindability and grinding characteristics of a particular stone.

Two tests have been used extensively to determine the resistance of stone aggregates to abrasion. The Deval test employs a cast iron cylinder of fixed dimensions which is mounted on a shaft at an angle of 30° to the axis of rotation. Depending upon stone density, a sample of specified particle size and weight is placed in the cylinder with 6 steel balls, after which the cylinder is rotated 10,000 times at 30 r.p.m. The abrasive loss is reported as the percentage of the original sample which passes a no. 12 sieve.

The Los Angeles test is similar to the Deval test. A cylindrical drum of fixed dimensions with an internal baffle is used. Various, but specified, gradations of stone are tested by placing the sample, together with a fixed number of steel balls, in the drum which is then rotated 500 or 1000 times at 30 r.p.m. The exact procedure depends on the particular gradation of stone used. Results are reported as in the Deval test.

Typical values of abrasive loss for limestone, dolomite, and marble, together with several other rock types (for comparison) are shown below:

	DEVAL TEST (%)	LOS ANGELES TEST (%)
Limestone	3.5- 8.5 (5.7 avg)	17-35 (26 avg)
Dolomite	3.5- 8.5 (5.5 avg)	16-35 (25 avg)
Marble	4.0-10.0 (6.3 avg)	23-67 (47 avg)
Basalt	3.1	14
Granite	4.3	38
Quartzite	3.3	28
Sandstone	7.0	38

Values for 23 of the major rock types (including limestone, dolomite, marble, amphibolite, basalt, breccia, chert, conglomerate, diabase, diorite, eclogite, epidosite, felsite, gabbro, gneiss, granite, peridotite, quartzite, sandstone, schist, serpentine, slate, and syenite) were generally in the range of 1.5-22.0%, for the Deval test, and 10-70%, for the Los Angeles test.

E. Hardness

The Dorry hardness test is made on a carefully prepared stone sample measuring 1 inch in diameter by 4 inches. The face of the core is held against a rotating, horizontal plate by a fixed load. Sand is fed continuously to the plate which is rotated 1000 times. The hardness is calculated from the loss in weight of the sample. The hardest rocks have the highest hardness values.

Although the test is no longer in general use, many values have been reported for various rocks. Typical values for carbonate rocks and some other types are:

Limestone	10-17 (14 avg)
Dolomite	11-17 (14 avg)
Marble	9-17 (13 avg)
Basalt	17
Granite	18
Quartzite	19
Sandstone	15

Most values for the principal types of rocks are within the range of 6-20.

F. Crushing Strength

To determine crushing strength, a 1 or 2 inch diameter sample having a height equal to diameter is tested under compression until failure. Ranges for carbonate rocks and a few other types are:

	psi x 10^{-3}
Limestone	10-28
Dolomite	10-40
Marble	10-30
Basalt	28-67
Granite	11-40
Quartzite	16-45
Sandstone	5-20

The compressive strength of chalk is very low, typically 1,000-4,000 psi.

G. Toughness

The toughness or resistance to impact of a rock is determined by subjecting a sample, having a diameter and height of about 1 inch, to the fall of a hammer of specified weight. Initially, the hammer is dropped 1 cm. after which the fall is increased 1 cm. at a time until the sample fails. The height of fall at failure is called the toughness.

Typical values of toughness for carbonate and noncarbonate rocks are:

Limestone	4-13 (8 avg)
Dolomite	4-14 (9 avg)
Marble	3- 9 (6 avg)
Basalt	19
Granite	9
Quartzite	16
Sandstone	11

Values for the principal rock types are generally between 3 and 32.

H. Specific Heat

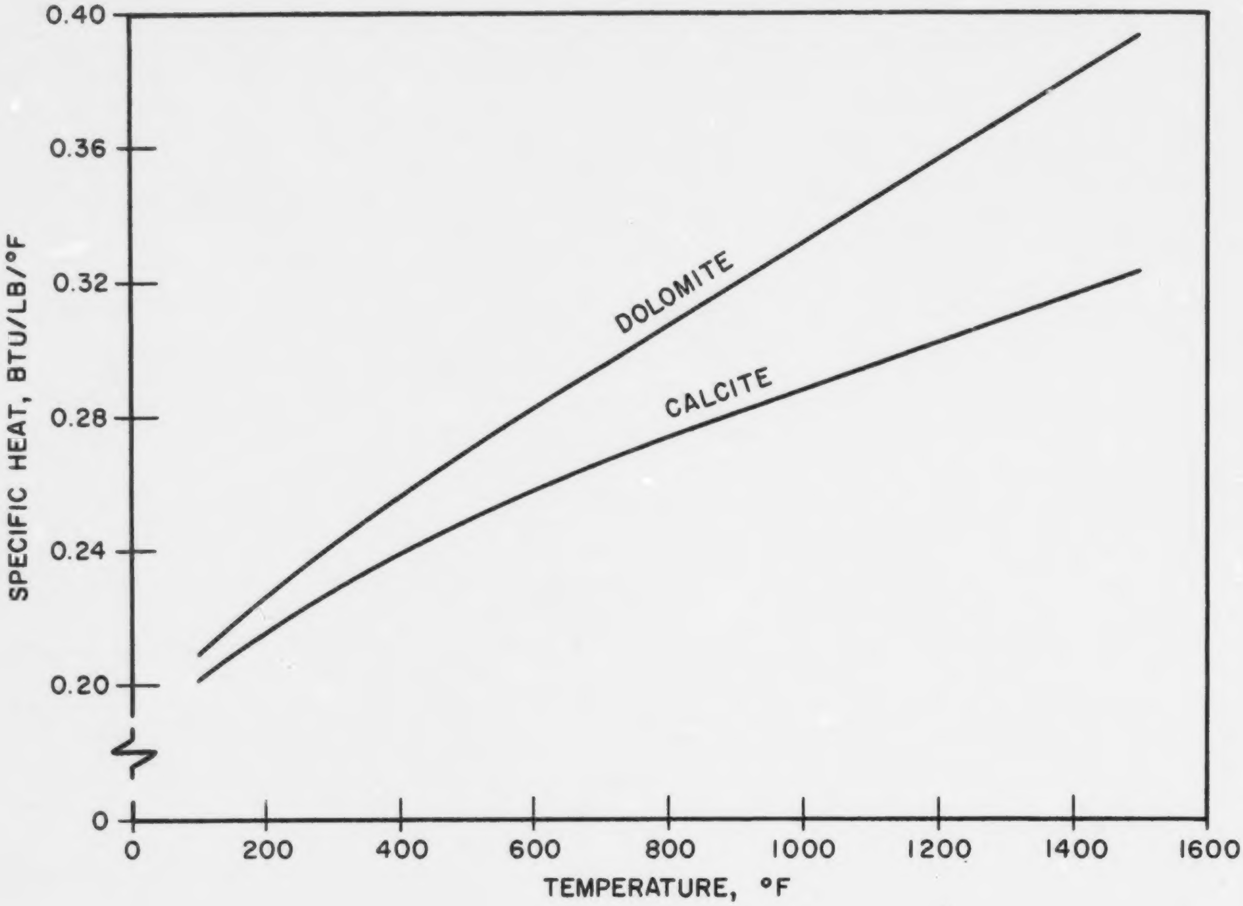
Curves for specific heats of calcite and dolomite are presented in Figure 35 as a function of temperature. As shown, values for dolomite are slightly higher than for calcite.

I. Thermal Conductivity

Values reported for marbles vary widely, but most are 5-8 cal/sec cm. °K at room temperature. Few values have been published for other carbonate rocks, but thermal conductivities of limestone and dolomite appear to be somewhat lower than that of marble.

FIGURE 35

SPECIFIC HEAT OF CALCITE AND DOLOMITE



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APPENDIX A

TABULATION OF QUARRY OPERATIONS IN THE UNITED STATES

LIMESTONE

State	County	No. of Quarries
Alabama	Bibb	1
	Calhoun	1
	Colbert	3
	Covington	1
	DeKalb	1
	Etowah	1
	Franklin	2
	Jackson	2
	Jefferson	5
	Lee	1
	Limestone	1
	Madison	4
	Marengo	1
	Marshall	1
	Morgan	4
	St. Clair	1
	Shelby	8
	Talladega	2
	Washington	1
Arizona	Cochise	1
	Coconino	2
	Gila	2
	Greenlee	1
	Pima	1
	Pinal	1
	Yavapai	2

LIMESTONE

State	County	No. of Quarries
Arkansas	Baxter	1
	Benton	4
	Boone	1
	Carroll	3
	Clark	1
	Craighead	1
	Crittenden	1
	Fulton	2
	Howard	1
	Independence	5
	Izard	4
	Lawrence	5
	Little River	2
	Marion	1
	Newton	1
	Pope	1
	Randolph	2
	Sharp	1
	Stone	1
	Washington	2
California	Calaveras	2
	Ed Dorado	5
	Inyo	1
	Kern	3
	Riverside	2
	San Benito	1
	San Bernardino	8
	San Luis Obispo	1

LIMESTONE

State	County	No. of Quarries
California (Cont'd)	San Mateo	1
	Santa Barbara	1
	Santa Clara	1
	Santa Cruz	2
	Shasta	1
	Tuolumne	2
	Ventura	1
Colorado	Boulder	1
	Chaffee	1
	Douglas	1
	El Paso	2
	Fremont	1
	Garfield	2
	Larimer	4
	San Miguel	1
Connecticut	Litchfield	2
Florida	Alachua	6
	Brevard	2
	Broward	16
	Charlotte	1
	Citrus	3
	Collier	6
	Dade	14
	Hernando	6
	Jackson	2
	Lee	3

LIMESTONE

State	County	No. of Quarries
Florida (Cont'd)	Levy	3
	Manatee	2
	Marion	10
	Monroe	2
	Palm Beach	6
	St. Lucie	1
	Sumter	3
	Suwannee	4
	Taylor	2
Georgia	Bartow	2
	Early	1
	Fannin	1
	Floyd	2
	Hall	1
	Houston	2
	Mitchell	1
	Walker	1
	Whitfield	1
Idaho	Bannock	1
	Bonneville	1
	Nez Perce	1
Illinois	Adams	10
	Boone	2
	Brown	1
	Calhoun	4

LIMESTONE

State	County	No. of Quarries
Illinois (Cont'd)	Carroll	14
	Christian	2
	Clark	3
	Clay	1
	Clinton	2
	Coles	2
	Cook	3
	Cumberland	1
	DeKalb	1
	Fayette	2
	Greene	3
	Hancock	3
	Hardin	6
	Henderson	4
	Henry	1
	Jackson	1
	Jersey	3
	Jo Daviess	21
	Johnson	2
	Kane	3
	Kendall	1
	Knox	1
	La Salle	4
	Lee	6
	Livingston	8
	Logan	1
	McDonough	2
	McHenry	1
	Macoupin	1

LIMESTONE

State	County	No. of Quarries
Illinois (Cont'd)	Madison	3
	Marion	1
	Massac	1
	Menard	2
	Mercer	2
	Monroe	1
	Montgomery	4
	Ogle	23
	Peoria	2
	Pike	6
	Pulaski	1
	Randolph	4
	Rock Island	4
	St. Clair	5
	Schuyler	1
	Scott	2
	Shelby	1
	Stephenson	15
	Union	3
	Vermilion	1
	Warren	2
	Washington	3
	Whiteside	3
	Will	3
	Winnebago	18

LIMESTONE

State	County	No. of Quarries
Indiana	Adams	2
	Allen	4
	Bartholomew	1
	Blackford	1
	Carroll	1
	Cass	2
	Clark	4
	Crawford	4
	Decatur	2
	Delaware	3
	Floyd	1
	Franklin	2
	Grant	1
	Hamilton	3
	Harrison	4
	Howard	1
	Huntington	2
	Jasper	2
	Jay	1
	Jennings	1
	Lawrence	13
	Madison	1
	Miami	1
	Monroe	15
	Morgan	1
	Orange	3
	Owen	2
	Perry	2
	Putnam	8

LIMESTONE

State	County	No. of Quarries
Indiana (Cont'd)	Randolph	2
	Ripley	2
	Scott	1
	Shelby	3
	Sullivan	1
	Switzerland	1
	Wabash	1
	Warrick	1
	Washington	1
	Wayne	1
	Wells	1
	White	2
Iowa	Adair	3
	Adams	2
	Allamakee	12
	Appanoose	3
	Benton	1
	Black Hawk	3
	Bremer	1
	Buchanan	11
	Butler	6
	Cass	2
	Cedar	4
	Cerro Gordo	6
	Chickasaw	2
	Clarke	1
	Clayton	18
	Clinton	11

LIMESTONE

State	County	No. of Quarries
Iowa (Cont'd)	Dallas	1
	Decatur	5
	Delaware	7
	Des Moines	4
	Dubuque	8
	Fayette	21
	Floyd	3
	Franklin	5
	Fremont	1
	Grundy	1
	Hamilton	1
	Hancock	1
	Hardin	3
	Harrison	2
	Henry	1
	Howard	5
	Humboldt	5
	Jackson	7
	Jasper	1
	Jefferson	2
	Johnson	4
	Jones	8
	Keokuk	3
	Lee	3
	Linn	10
	Louisa	2
	Madison	9
	Mahaska	2
	Marion	3

LIMESTONE

State	County	No. of Quarries
Iowa (Cont'd)	Marshall	1
	Mills	2
	Mitchell	12
	Montgomery	2
	Muscatine	1
	Page	2
	Pocahontas	1
	Pottawattamie	3
	Poweshiek	2
	Scott	5
	Story	2
	Tama	1
	Taylor	2
	Union	1
	Van Buren	5
	Wapello	1
	Washington	6
	Wayne	1
	Webster	2
	Winneshiek	11
	Worth	2
	Various	35
Kansas	Allen	4
	Anderson	2
	Atchison	4
	Bourbon	2
	Brown	1

LIMESTONE

State	County	No. of Quarries
Kansas (Cont'd)	Butler	5
	Chase	4
	Chautauqua	1
	Cherokee	2
	Clay	4
	Cloud	1
	Coffey	2
	Cowley	3
	Crawford	1
	Dickinson	4
	Doniphan	7
	Elk	2
	Ellis	2
	Franklin	8
	Geary	1
	Greenwood	2
	Jackson	1
	Jefferson	5
	Jewell	22
	Johnson	8
	Labette	3
	Leavenworth	5
	Linn	4
	Lyon	2
	McPherson	1
	Marion	4
	Marshall	4
	Miami	3
	Montgomery	5
	Morris	5

LIMESTONE

State	County	No. of Quarries
Kansas (Cont'd)	Nemaha	3
	Neosho	5
	Ness	1
	Osage	1
	Phillips	1
	Pottawatomie	3
	Republic	1
	Rice	1
	Riley	14
	Shawnee	6
	Smith	1
	Wallace	1
	Washington	3
	Wilson	3
	Woodson	2
	Wyandotte	3
	Various	44
Kentucky	Adair	3
	Allen	1
	Anderson	1
	Barren	1
	Bourbon	1
	Boyle	2
	Breckinridge	2
	Bullitt	2
	Butler	1
	Caldwell	2
	Calloway	1

LIMESTONE

State	County	No. of Quarries
Kentucky (Cont'd)	Carter	4
	Casey	1
	Christian	3
	Clinton	2
	Crittenden	1
	Cumberland	1
	Edmonson	1
	Estill	2
	Fayette	4
	Fleming	1
	Franklin	2
	Garrard	1
	Grayson	2
	Green	1
	Greenup	1
	Hardin	5
	Harlan	1
	Harrison	1
	Hart	1
	Henry	1
	Jackson	2
	Jefferson	4
	Jessamine	2
	Laurel	1
	Lee	1
	Letcher	3
	Livingston	3
	Logan	1
	Madison	1

LIMESTONE

State	County	No. of Quarries
Kentucky (Cont'd)	Marion	2
	Meade	3
	Menifee	1
	Mercer	2
	Metcalfe	1
	Monroe	1
	Montgomery	1
	Morgan	4
	Muhlenberg	1
	Nelson	1
	Nicholas	1
	Ohio	2
	Oldham	4
	Pendleton	2
	Pike	2
	Powell	2
	Pulaski	2
	Rockcastle	3
	Rowan	2
	Scott	1
	Simpson	1
	Taylor	1
	Todd	1
	Trigg	1
	Warren	4
	Wayne	1
	Wolfe	1

LIMESTONE

State	County	No. of Quarries
Maine	Aroostook	1
	Kennebec	1
	Knox	2
Maryland	Allegany	1
	Baltimore	3
	Carroll	2
	Frederick	6
	Garrett	3
	Howard	1
	Washington	6
Massachusetts	Berkshire	4
Michigan	Alpena	1
	Arenac	4
	Charlevoix	1
	Cheboygan	2
	Delta	1
	Eaton	1
	Emmet	1
	Houghton	1
	Huron	1
	Jackson	1
	Leelanau	1
	Mackinac	1
	Monroe	3
	Presque Isle	3
	Schoolcraft	1
	Wayne	1

LIMESTONE

State	County	No. of Quarries
Minnesota	Blue Earth	1
	Dakota	2
	Dodge	3
	Fillmore	8
	Goodhue	9
	Houston	18
	Le Sueur	1
	Mower	4
	Olmsted	6
	Rice	2
	Scott	1
	Steele	1
	Wabasha	4
	Washington	3
	Winona	5
Mississippi	Clay	1
	Rankin	1
	Warren	1
Missouri	Adair	1
	Barry	1
	Barton	1
	Bates	4
	Boone	4
	Buchanan	3
	Caldwell	4
	Callaway	3
	Camden	1

LIMESTONE

State	County	No. of Quarries
Missouri (Cont'd)	Cape Girardeau	4
	Cass	2
	Christian	4
	Clark	1
	Clay	5
	Clinton	4
	Cole	1
	Cooper	1
	Dade	1
	Dallas	1
	Daviess	2
	DeKalb	3
	Franklin	3
	Gentry	1
	Greene	4
	Grundy	3
	Harrison	5
	Henry	6
	Hickory	1
	Holt	5
	Howard	1
	Howell	1
	Iron	1
	Jackson	16
	Jasper	4
	Jefferson	6
	Johnson	4
	Knox	2
	Laclede	2

LIMESTONE

State	County	No. of Quarries
Missouri (Cont'd)	Lafayette	1
	Lawrence	1
	Lewis	1
	Lincoln	5
	Linn	1
	Livingston	3
	Marion	2
	Mercer	4
	Miller	1
	Moniteau	1
	Monroe	3
	Montgomery	3
	Newton	1
	Nodaway	5
	Ozark	1
	Perry	1
	Pettis	2
	Phelps	2
	Pike	4
	Platte	2
	Pulaski	1
	Ralls	2
	Randolph	3
	Ray	3
	Reynolds	1
	St. Charles	6
	St. Francois	2
	St. Louis	13

LIMESTONE

State	County	No. of Quarries
Missouri (Cont'd)	Ste. Genevieve	3
	Saline	4
	Scotland	1
	Scott	1
	Shannon	1
	Shelby	1
	Vernon	3
	Warren	2
	Wayne	1
	Wright	1
	Various	12
Montana	Broadwater	1
	Carbon	1
	Deer Lodge	1
	Gallatin	1
	Jefferson	2
Nebraska	Cass	12
	Dixon	1
	Douglas	1
	Gage	3
	Lancaster	2
	Nemaha	1
	Nuckolls	1
	Otoe	1
	Pawnee	1
	Richardson	2
	Saline	1
	Sarpy	4

LIMESTONE

State	County	No. of Quarries
Nebraska (Cont'd)	Saunders	1
	Seward	1
	Thayer	1
	Washington	2
Nevada	Clark	2
	Lyon	1
	White Pine	1
New Jersey	Sussex	2
	Warren	1
New Mexico	Bernalillo	3
	Chaves	1
	Dona Ana	1
	Eddy	1
	Grant	1
	Lincoln	3
	Luna	1
	Otero	2
	Rio Arriba	3
	San Juan	1
	Santa Fe	1
	Taos	1
	Torrance	1

LIMESTONE

State	County	No. of Quarries
New York	Albany	2
	Cayuga	1
	Clinton	1
	Columbia	2
	Dutchess	2
	Erie	4
	Genesee	4
	Greene	5
	Herkimer	3
	Jefferson	1
	Lewis	3
	Livingston	1
	Madison	3
	Montgomery	1
	Niagara	1
	Oneida	1
	Onondaga	4
	Ontario	2
	Orange	1
	Orleans	1
	Saratoga	2
	Schoharie	4
	Seneca	1
	Tompkins	1
	Ulster	3
	Washington	2
	Wayne	1

LIMESTONE

State	County	No. of Quarries
North Carolina	Cleveland	1
	Craven	1
	Henderson	2
	Jones	1
	New Hanover	2
	Onslow	1
	Swain	1
Ohio	Adams	1
	Allen	5
	Athens	2
	Auglaize	1
	Belmont	4
	Brown	1
	Clermont	1
	Crawford	1
	Delaware	4
	Erie	3
	Fayette	1
	Franklin	1
	Gallia	1
	Greene	6
	Guernsey	2
	Hancock	3
	Hardin	1
	Harrison	1
	Highland	2
	Hocking	1
	Holmes	1
	Jackson	2

LIMESTONE

State	County	No. of Quarries
Ohio (Cont'd)	Lawrence	4
	Logan	2
	Lucas	3
	Madison	2
	Mahoning	6
	Marion	3
	Mercer	1
	Miami	4
	Monroe	1
	Montgomery	3
	Morgan	3
	Muskingum	4
	Noble	3
	Ottawa	2
	Paulding	2
	Perry	2
	Pickaway	1
	Preble	2
	Putnam	3
	Sandusky	3
	Seneca	2
	Shelby	1
	Stark	2
	Summit	2
	Tuscarawas	3
	Union	2
	Van Wert	2
	Vinton	1
	Wayne	1
	Wood	4
	Wyandot	3

LIMESTONE

State	County	No. of Quarries
Oklahoma	Atoka	1
	Bryan	1
	Caddo	3
	Carter	2
	Cherokee	1
	Choctaw	4
	Cleveland	1
	Coal	1
	Comanche	1
	Creek	1
	Grady	1
	Hughes	1
	Johnston	1
	Kay	2
	Kiowa	10
	McCurtain	2
	McIntosh	3
	Marshall	1
	Mayes	2
	Murray	9
	Muskogee	1
	Nowata	2
	Oklahoma	1
	Okmulgee	1
	Osage	3
	Pawnee	1
	Payne	1
	Pittsburg	2

LIMESTONE

State	County	No. of Quarries
Oklahoma (Cont'd)	Pontotoc	4
	Pottawatomie	2
	Rogers	1
	Seminole	7
	Sequoyah	1
	Tulsa	5
	Washington	2
	Various	1
Oregon	Baker	3
	Multnomah	1
Pennsylvania	Adams	2
	Armstrong	4
	Bedford	2
	Berks	7
	Blair	8
	Bucks	6
	Butler	5
	Centre	8
	Chester	3
	Clarion	2
	Clinton	3
	Columbia	2
	Cumberland	3
	Dauphin	3
	Fayette	2
	Franklin	4
	Fulton	2

LIMESTONE

State	County	No. of Quarries
Pennsylvania (Cont'd)	Huntingdon	4
	Lancaster	14
	Lawrence	5
	Lebanon	4
	Lehigh	8
	Lycoming	2
	Mercer	1
	Mifflin	4
	Monroe	1
	Montgomery	4
	Montour	3
	Northampton	10
	Northumberland	1
	Perry	1
	Schuylkill	1
	Snyder	1
	Somerset	2
	Union	3
	Venango	1
	Washington	1
	Westmoreland	4
	York	8
Rhode Island	Providence	1
South Carolina	Berkeley	1
	Cherokee	1
	Dorchester	1

LIMESTONE

State	County	No. of Quarries
South Dakota	Custer	1
	Lawrence	2
	Pennington	5
Tennessee	Anderson	2
	Bedford	1
	Benton	1
	Blount	1
	Bradley	2
	Campbell	3
	Cannon	1
	Carter	1
	Claiborne	1
	Clay	1
	Cocke	2
	Coffee	2
	Cumberland	2
	Davidson	7
	Decatur	1
	DeKalb	1
	Dickson	1
	Fayette	1
	Fentress	1
	Franklin	4
	Giles	1
	Grainger	1
	Greene	5
	Grundy	1
	Hamblen	1

LIMESTONE

State	County	No. of Quarries
Tennessee (Cont'd)	Hamilton	2
	Hancock	1
	Hardin	1
	Humphreys	1
	Jefferson	5
	Johnson	1
	Knox	8
	Lincoln	2
	Loudon	1
	McMinn	2
	Macon	1
	Marion	4
	Marshall	2
	Maury	1
	Meigs	2
	Monroe	1
	Montgomery	1
	Moore	1
	Overton	1
	Pickett	1
	Polk	1
	Putnam	2
	Rhea	1
	Roane	1
	Robertson	1
	Rutherford	3
	Sequatchie	1
	Sevier	2
	Smith	1
	Stewart	1

LIMESTONE

State	County	No. of Quarries
Tennessee (Cont'd)	Sullivan	1
	Sumner	3
	Unicoi	1
	Union	1
	Warren	2
	Washington	5
	Wayne	1
	White	2
	Williamson	2
	Wilson	3
Texas	Anderson	1
	Bee	1
	Bell	2
	Bexar	7
	Bosque	3
	Brown	4
	Burnet	1
	Callahan	2
	Coleman	4
	Collin	4
	Comal	2
	Comanche	2
	Coryell	3
	Dallas	2
	Dawson	1
	DeWitt	1
	Eastland	1
	Ector	1

LIMESTONE

State	County	No. of Quarries
Texas (Cont'd)	Ellis	4
	El Paso	2
	Freestone	1
	Gaines	1
	Gillespie	1
	Grayson	2
	Guadalupe	1
	Haskell	1
	Hidalgo	1
	Hill	2
	Hood	4
	Howard	2
	Hutchinson	1
	Jack	2
	Johnson	2
	Jones	1
	Kaufman	2
	Kleberg	1
	Lamb	1
	Lavaca	1
	Leon	1
	Limestone	1
	Lipscomb	1
	McCulloch	2
	McLennan	1
	Mills	3
	Mitchell	1
	Nolan	1
	Palo Pinto	1

LIMESTONE

State	County	No. of Quarries
Texas (Cont'd)	Parker	2
	Potter	1
	Robertson	1
	San Patricio	1
	San Saba	2
	Scurry	2
	Shackelford	1
	Tarrant	3
	Taylor	2
	Travis	4
	Uvalde	4
	Williamson	5
	Wise	14
	Young	1
	Various	6
Utah	Cache	1
	Daggett	1
	Duchesne	1
	Millard	1
	Morgan	1
	Salt Lake	2
	Tooele	2
	Utah	3
	Wasatch	1
Vermont	Chittenden	2
	Franklin	1
	Rutland	1

LIMESTONE

State	County	No. of Quarries
Virginia	Alleghany	1
	Appomattox	1
	Augusta	5
	Bland	2
	Botetourt	3
	Campbell	3
	Frederick	5
	Giles	3
	Highland	1
	Lee	3
	Louisa	1
	Montgomery	4
	Pulaski	5
	Rockbridge	1
	Rockingham	4
	Russell	3
	Scott	2
	Shenandoah	4
	Smyth	2
	Tazewell	3
	Warren	2
	Washington	3
	Wise	2
	Wythe	2
Washington	King	1
	Okanogan	1
	Pend Oreille	1
	San Juan	1
	Snohomish	1

LIMESTONE

State	County	No. of Quarries
Washington (Cont'd)	Stevens	2
	Whatcom	2
West Virginia	Berkeley	4
	Grant	2
	Greenbrier	4
	Hardy	1
	Mineral	2
	Monongalia	2
	Pendleton	2
	Pocahontas	2
	Preston	3
	Randolph	3
Wisconsin	Brown	9
	Buffalo	7
	Calumet	5
	Columbia	4
	Crawford	15
	Dane	31
	Dodge	5
	Door	3
	Dunn	3
	Fond du Lac	11
	Grant	27
	Green	24
	Green Lake	1
	Iowa	24
	Jackson	1

LIMESTONE

State	County	No. of Quarries
Wisconsin (Cont'd)	Jefferson	2
	Juneau	2
	Kewaunee	1
	La Crosse	3
	Lafayette	20
	Manitowoc	1
	Marquette	1
	Milwaukee	2
	Monroe	10
	Oconto	2
	Outagamie	9
	Pepin	4
	Pierce	10
	Polk	1
	Racine	2
	Richland	16
	Rock	14
	St. Croix	8
	Sauk	17
	Shawano	2
	Sheboygan	1
	Trempealeau	4
	Vernon	29
	Walworth	1
	Waukesha	21
	Waupaca	2
	Winnebago	13
	Various	25

LIMESTONE

State	County	No. of Quarries
Wyoming	Albany	3
	Crook	1
	Laramie	1
	Platte	1
	Teton	1

DOLOMITE

State	County	No. of Quarries
Alabama	Bibb	1
	Jefferson	3
	Shelby	1
California	Monterey	1
	San Benito	1
	Tulare	1
Colorado	Douglas	1
	Fremont	1
Connecticut	Litchfield	2
Illinois	Boone	1
	Cook	3
	DeKalb	1
	Du Page	1
	Kankakee	2
	Lee	4
	Ogle	1
	Whiteside	2
	Will	1
	Winnebago	1
Indiana	Adams	1
	Cass	1
	Delaware	1
	Madison	1
	Newton	1
	Pulaski	1
	Rush	3

DOLOMITE

State	County	No. of Quarries
Iowa	Black Hawk	1
	Cerro Gordo	1
	Dubuque	1
	Howard	2
	Jackson	1
	Worth	1
Massachusetts	Berkshire	1
Michigan	Chippewa	1
	Dickinson	1
	Mackinac	1
	Monroe	3
	Schoolcraft	2
Minnesota	Blue Earth	3
	Le Sueur	2
	Scott	3
	Washington	1
	Winona	1
Missouri	Cole	1
	Franklin	2
	Oregon	1
	Phelps	1
	Pike	1
	St. Francois	1
Nevada	Clark	1
	Pershing	1

DOLOMITE

State	County	No. of Quarries
New Mexico	Grant	1
New York	Dutchess	1
	Monroe	3
	Montgomery	1
	Niagara	2
	Rockland	1
	St. Lawrence	2
	Warren	1
	Washington	1
	Wayne	1
Ohio	Adams	2
	Clark	1
	Clinton	1
	Erie	1
	Fayette	2
	Hardin	1
	Highland	1
	Logan	1
	Lucas	2
	Mercer	1
	Ottawa	2
	Pike	1
	Ross	1
	Sandusky	5
	Seneca	2
	Van Wert	1
	Wood	2
	Wyandot	1

DOLOMITE

State	County	No. of Quarries
Oklahoma	Johnston	1
Pennsylvania	Adams	1
	Armstrong	1
	Berks	1
	Bucks	1
	Butler	1
	Centre	1
	Chester	1
	Cumberland	3
	Jefferson	1
	Lancaster	1
	Lebanon	1
	Lehigh	1
	Montgomery	1
	York	1
Texas	Burnet	1
	El Paso	1
Utah	Tooele	1
Vermont	Rutland	1
Virginia	Alleghany	1
	Botetourt	2
	Clarke	1
	Giles	1
	Montgomery	2
	Roanoke	2

DOLOMITE

State	County	No. of Quarries
Virginia (Cont'd)	Rockingham	2
	Russell	1
	Scott	2
	Shenandoah	1
	Wythe	1
Washington	Stevens	2
West Virginia	Grant	1
	Harrison	2
	Jefferson	3
	Mineral	1
Wisconsin	Brown	1
	Calumet	1
	Dodge	1
	Fond du Lac	1
	Manitowoc	1
	Waukesha	4

MARBLE

State	County	No. of Quarries
Alabama	Talladega	3
Arizona	Maricopa	3
	Pima	3
	Pinal	1
	Yuma	1
Arkansas	Independence	1
California	Inyo	4
	San Bernardino	1
	Tuolumne	7
Colorado	Chaffee	1
	Fremont	5
Georgia	Chattooga	1
	Gilmer	2
	Pickens	6
Idaho	Various	4
Maryland	Harford	1
Missouri	Greene	1
	Jasper	1
	Jefferson	1
	Madison	1
	Ste. Genevieve	2

MARBLE

State	County	No. of Quarries
Montana	Madison	1
	Park	2
Nevada	Mineral	1
New Jersey	Warren	1
New York	St. Lawrence	1
	Westchester	1
North Carolina	Cherokee	1
Tennessee	Blount	3
	Grainger	1
	Knox	3
	Loudon	1
	Union	1
Texas	Burnet	30
	Llano	2
Vermont	Rutland	5
	Windsor	1
Virginia	Rockingham	1
Washington	Stevens	8
Wyoming	Platte	1

MARL

State	County	No. of Quarries
Indiana	Elkhart	2
	Kosciusko	1
	Lagrange	3
	Marshall	4
	Noble	1
	St. Joseph	1
	Steuben	3
Michigan	Allegan	2
	Barry	2
	Berrien	2
	Branch	1
	Calhoun	2
	Cass	2
	Hillsdale	1
	Jackson	1
	Kalamazoo	3
	St. Joseph	1
Minnesota	Cass	1
	Wadena	1
Mississippi	Rankin	1
	Warren	1
Nevada	Nye	1
South Carolina	Dorchester	1
	Orangeburg	1

MARL

State	County	No. of Quarries
Texas	Bexar	1
Virginia	Clarke	1
	Nansemond	1
	York	1
	Hampton	1

SHELL

State	County	No. of Quarries
Alabama	Mobile	2
California	San Mateo	2
Florida	Duval	1
	Hillsborough	1
	Lee	1
	Pinellas	1
	Walton	1
Louisiana	Cameron	1
	Orleans	1
	St. Mary	3
	St. Tammany	4
Maryland	Baltimore	1
Pennsylvania	Berks	1
Texas	Aransas	1
	Calhoun	4
	Nueces	2
	Various	1
Virginia	Isle of Wight	1

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